Project no. TIP5-CT-2006-031415

INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

D3.1.1 Definition of key parameters

Due date of deliverable: May 2007

D3.1.2 Report on cost drivers for goal-directed innovation

Due date of deliverable: February 2008

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Start date of project: 1 September 2006 Duration: 36 months

Organisation name of lead contractor for this deliverable: DB (Wolfgang Grönlund, Dr. Gunnar Baumann)

Final

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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)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

Abbreviations

Abbreviation/acronym	Description
LCC	Life cycle costing/ costs
S&C	Switches and crossing
DLD	Driving and locking devices
TP	Technical place (SAP R/3 Netz)
MA	maintenance activity
MTN	maintenance
MGT	Million Gross Tonnes
IM	Infrastructure Manager

Definitions

BV categories

Term	Description
Short-range planned actions after inspection	mainly include adjustment, build up welding and minimal repairs as actions after inspection
Long-range planned actions after inspection	include replacement of frogs, switch rails and check rails as part of the condition based maintenance

1. Executive Summary

The aim of the Innotrack project is to reduce Life Cycle Costs of about 30%. Therefore the purpose of this deliverable is to identify the key parameters for optimizing the track related performance of S&C.

This is be done by embedding the analysis of real cost factors into the identification of track related components and the general cost factors of a S&C. Key parameters for optimization are then identified by combining the results of cost factor analysis with the identified components and cost factors.

Because of insufficient infrastructure data bases for getting data of costs for maintenance activities as far as possible representative lines have been selected for the cost factor analysis.

The analysis of the selected high speed line from DB (with UIC 60 S&C, mixed traffic with about 17.5 MGT/year (average) and 458 chosen S&C) has identified the following key parameters:

a. **50%** of the overall costs are for **inspection, service and test measures.** These are thus the main cost drivers overall at the selected DB line.

b. **excluding inspection/service/test** the main cost drivers with 65% are renewal of half set of switch (35%), large elements [1] (17%) and frog renewal (13%).

   The other activities like welding, corrective maintenance (e.g. minimal repair), tamping etc. sum up “only” to 35% on the selected line.

c. First results from another DB analysis confirm this conclusions in general but show that the **costs for renewal of switch rails are roughly equal to the costs for renewal of frogs**.

The analysis of the maintenance costs of the selected line from BV (with mixed traffic (about 25% passenger and 75% freight traffic) with assumed 18 MGT/year) has identified the following key parameters:

The main cost drivers (**without inspection/service/test**) are

- Short-range planned actions after inspections with 30% (mainly including adjustment, build up welding and minimal repairs as actions after inspection)
- Long-range planned actions after inspection with 26% (including replacement of frogs, switch rails and check rails as part of the condition based maintenance)
- Costs for inspections & predetermined maintenance with 17%.

The costs for these measures sum up to 73% while the amount for the other activities inspection, grinding and tamping are of 27%.

Because the distribution of the maintenance costs to the detailed activities for short- and long-range planned actions and for failure costs is not yet available further analysis is required to break down the costs to types of S&Cs and to the associated maintenance activities and components of a S&C. As well as to investigate is the difference between the costs for DB and BV.

Follow-up analyses for other routes with different characteristics are under way. It will be reported in later deliverables which will also include data analysis from other railways.

[1] The data bases do not include detailed specifications of the category 'large elements', but this category includes large components like frogs, switch rails, check rails etc.

Workpackage	3.1 - Switches and Crossings			**Start date or starting event:**			T0
Participant id	BV	ADIF	Chalmers	DB	VAE	VCSA	Prorail
Person-months per participant	9	1.5	20	40	6	7	1.5
Participant id	RRUK	Corus	NR				
Person-months per participant	10	1	1.5				

Objectives

- Establishment of a predictive model for switch dynamics and deterioration.
- Prediction of the effect of increased axle loads on switches and crossings.
- Development of new and innovative switch designs to decrease maintenance and to handle increased axle loads
- Identification of best practices, improvement and implementation of innovative maintenance strategies and techniques

Description of work

Task 3.1.1 – Duty Conditions

Duty conditions: measurements of the influence of vehicles (dynamic forces, esp. lateral and impact forces to the frog) on the switch, simulations. Compare with simulations, calculation of the resulting forces and stresses in the switch, based on statistical data for vehicle conditions (wheel profiles)

Task 3.1.2 – Failure catalogue

Failure catalogue, influence of different loads, optimization of switch design, material and maintenance technology and strategy

Task 3.1.3 – Best practice benchmarks

Benchmark of the experience of the partners for indicated switches and duty conditions to find “best practice”

Task 3.1.4 – Cost drivers

Identification of cost drivers in the switch (track) in terms of LCC

Task 3.1.5 - Materials

Optimize material – best choices and new materials

Task 3.1.6 - Optimisation

Optimize a) global and local geometry (alignment, profiles of rail, frog)

Optimize b) horizontal track-elasticity and vertical frog-elasticity incl. proof of reduced deterioration

Task 3.1.7 - Maintenance

Optimize maintenance in all areas including lubrication, grinding, inspection technologies

Deliverables

D3.1.1 Definition of key parameters and constraints (M9)
D3.1.2 Report on Cost drivers for goal-directed innovations (M18)

Milestones and expected results

M3.1.1 Ranking of problems in switches in terms of their economic impact (M16)

2. Introduction

The aim of the Innotrack project is to reduce Life Cycle Costs of about 30%. Therefore the purpose of this document is to identify the key parameters for optimizing the track related performance of S&C.

To define key parameters and constraints in optimization of S&C in respect to a reduced LCC you have to take into account the analysis of cost factors.

This leads to the following proceeding:

- In the first step the track related components of a S&C are to be identified followed by the compilation of the general cost factors which result from maintenance activities. This gives an unvalued overview over all possible factors.
- In the second step real cost factors based on the analysis of maintenance costs are to be identified.
- Putting steps one and two together the analysis of the cost factor results give a valued overview over that parameters which have the greatest impact on costs and are therefore of greatest importance in the track related optimization of S&C: the **key parameters for track related optimization of S&C**.

This approach explains the merging of deliverables D3.1.1 and D3.1.2 in a single document.

3. Overview of the methodology for identification of key parameters

The previous section explained why deliverables D3.1.1 and D3.1.2 are merged together. To go more into detail the analysis of cost factors (D3.1.2) is embedded into the identification of track related components and the general cost factors of a S&C (D3.1.1). Key parameters for optimization (D3.1.1 cont.) are then identified by combining the results of cost factor analysis with the identified components and cost factors.

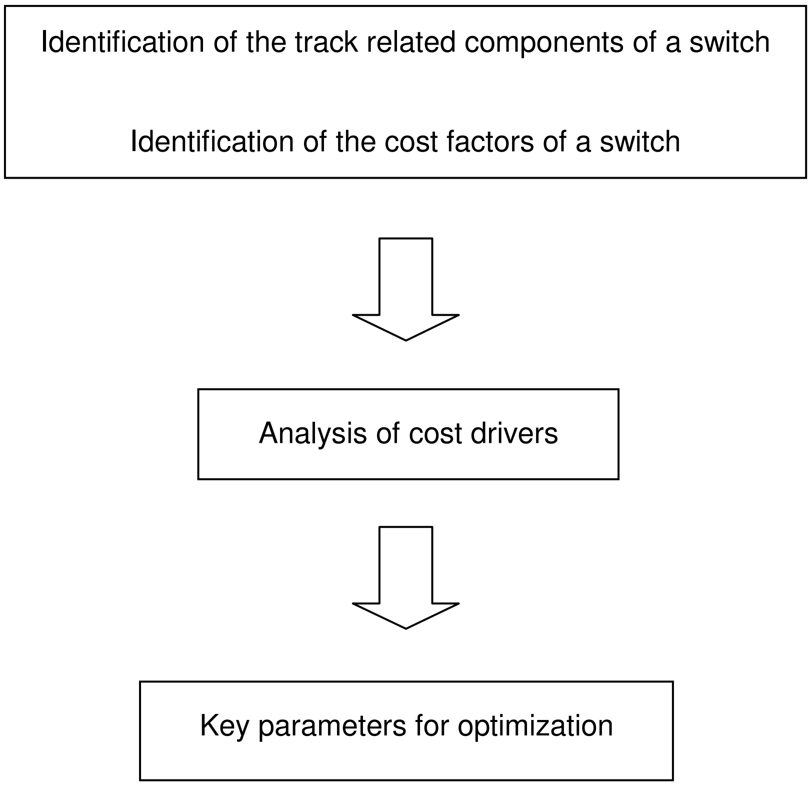


Figure 1 Overview of the proceeding for identification of track related key parameters of S&C

In the ongoing work of WP3.1 the identified key parameters are to be optimized. In this respect deliverable D3.1.1 / D3.1.2 builds the base for that ongoing work.

Constraints:

- Inspection and service activities are based on planned maintenance;
- Insufficient infrastructure data bases for getting data of costs for maintenance with a detailed allocation to several components and maintenance actions;

This is obviously a problem for all railways. Therefore as the solution adopted in SP 3.1 specific routes have been chosen and analysed.

- As far as possible representative lines are selected for the cost factor analysis.

4. Identification of parameters

In this chapter, general parameters of track related components and cost factors of a S&C are described. No cost analysis is carried out here.

4.1 Identification of track related components of a S&C

Figures 2 and 3 show in general the components of the switch and crossing section.

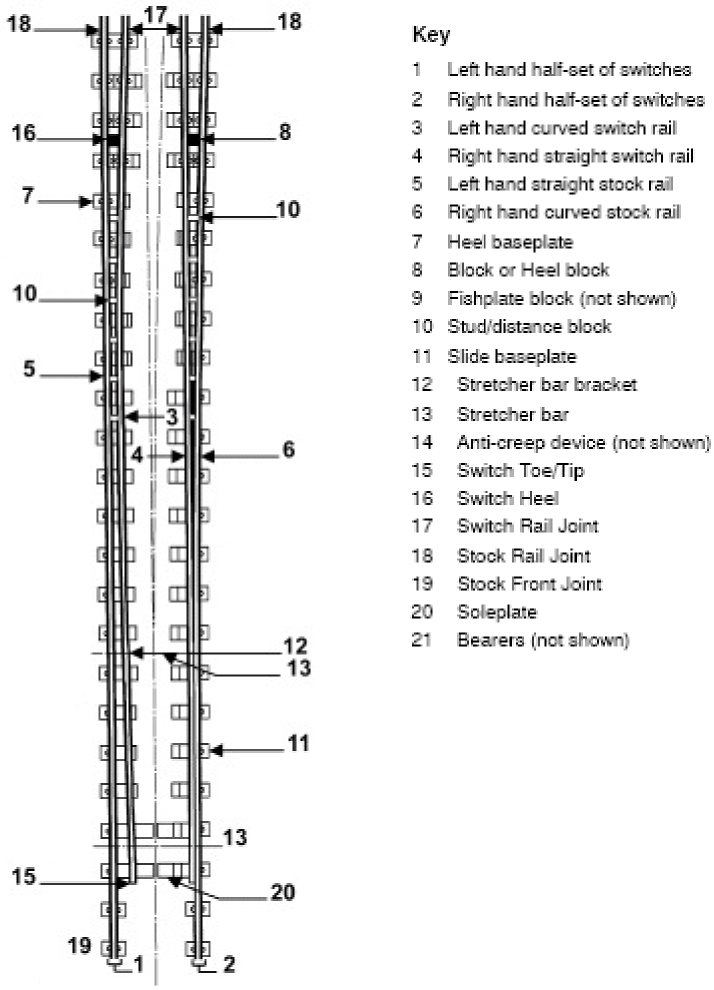
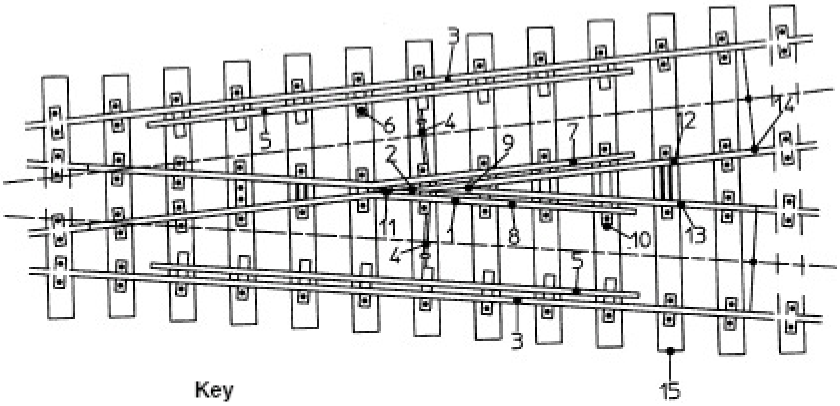


Figure 2 Components of a switch



Key

1	Common crossing	9	Crossing Vee
2	Crossing nose	10	Crossing baseplate
3	Outside rail	11	Block
4	Check rail Strut	12	Point rail
5	Check rail	13	Splice rail
6	Check rail support	14	Heel of crossing
7	Left hand wing (rail)	15	Bearers
8	Right hand wing (rail)		

Figure 3 Components of a crossing

Within the Innotrack project and in respect to the level of detail of the data bases employed in this study the following main components are of interest:

- Switch rail
- Stock rail
- Frogs
- Check rail
- Fastenings
- Sliding chairs
- Blade rollers
- Plates
- Sleepers

4.2 Identification of cost factors of a S&C

In general there are three main groups of activities which lead to or include activities that create costs: inspections, service and maintenance.

Service is e.g. lubrication. Maintenance activities are e.g. repair, renewal, grinding, tamping, welding.

In respect to the level of detail of the data bases the main cost of a S&C result from:

- inspection
- service
- tests (i.e. ultrasonic test)
- corrective maintenance
  - repair
  - renewal

- grinding
- tamping
- welding
- (penalties; only in single countries and not of interest within this deliverable)

Note 1: In chapter 5 "Cost factors DB" maintenance activities contain corrective maintenance (see table 1, Allocation activities to main groups (Cluster)).

Note 2: In chapter 6 "Cost factors BV" maintenance costs are related to the terms “short-range planned”, “long-range planned” and “failure costs”. These terms need to be detailed to break down the costs with respect to types of S&C and to the associated maintenance activities and components of a S&C.

5. Cost factors DB

Coordination: DB, Nicole Kumpfmüller

The aim of Innotrack is reducing the LCC about 30%. The task of this working deliverable is identifying the cost factors of S&Cs and crossing and selecting critical items for focusing within the following activities. Because SP1, SP3 and SP6 needed this information it was carried out as a joint task.

Steps:

- National Workshop
- Selection of route and analysis (start with one route and approx. 500 S&C)
- SAP R/3 queries (filtering data by maintenance activities for S&C)
- Access database for analysis and storage
- Extension of database and validation of data

5.1 National Workshop

The workshops have been the first step to identify the national problems. The aim was that the critical S&C and the main problems should be identified and directed to SP3.

Nr.	Question	Relevance	Cause	Boundary condition	Solution	Track/Line	*Innotrack addressed questions*
1	Common crossing wear	4 / 4	Crossing construction, wheel set profile (concave running?)		Threshold for wheel profile optimisation, material grade, geometry and construction	Common crossing test track Haste - ???	How can crossing wear be reduced?
	Common crossing wear: Deformation, head checks						Can we adopt a meaningful threshold for wheel profile, and if so, what is it?
	Wear development on common crossings: which steel grade is necessary?						What material grades are essential?
	Common crossing construction - Cast crossing weld acceptability						Can crossing wear be avoided with the application of specialised crossing construction?
2	Heat conduction in built-up welds	3 / 1			Quality assurance		How can quality assurnace of built-up welds be accomplished? Best practice: Optimum process for built-up welds - short track closures versus quality? Durability of built-up welds in connection with load and wear policies? At the moment there is no verification data available Has operational relevance to track closures.
3	Optimum maintenance? (How, when, what?)	3 / 1			Detail essential		What should optimum switch maintenance look like? (questions of organisation, procedure, details and materials)
4	Horizontal wear in a switch blade mechanism: right to left, or left to right	3 / 2		Smaller radius (less than 500m)	Backenschiene + ZGV Volumenvergütung generell? - ???		Which solution can be adopted against horizontal wear in switch blade mechanism on tight radius curves?
					Use tempered components - significance?		Would application of tempered materials/components be reasonable?
5	Switch blade crack; switch blade break	1 / 1			Always use Witec blades		
6	Head checks on switch blades						
7	At what speed should we intall flexible timbers?	1 / 1		Track bed; bogie construction			

S&C - DLD

Nr.	Question	Relevance	Cause	Boundary condition	Solution	Track/Line	*Innotrack addressed questions*
1	Connection of control centre to drive	4/1	Manufacturer specified interfaces	Migration to a newer system	Excellent interfaces with the control system		
2	Inspection period	4/1	Various periods for superstructure and LST		Harmonised and optimised control process		Actions of other railways
3	Energuy for point heating	4/2	High energy costs for point heating	Winter, low temperatures, large radii	Optimisation of point heating, alternative energy sources, insulation	Check out ground heating - ???	Best practise
4	Point-end detection system	3/4	Yes-no answer		End detection through gap measurement, documentation of development of faults	1733	
5	Specification of the point drive, control and monitoring system	3/3	High maintenance expenditure		Specification		
6	Specification of the monitoring system	3/3	No standards, no parameters for the monitored values	Heavily used routes	Standardised monitoring system	Investigation area - existing interface monitoing systems	How much should be monitored? Which switches? Pro active maintenance? Best practise
7	Lubrication of the switch Clamp lock Slide chair ???	4/3	Short service life and inapplicability for all specialised application areas	Heavy use, frequent switch operation	Optimisation of the lubricant to extend the service life	Investigation area - Lubrication	

Legend:

- Figures in column "relevance":
  - scale of 1 to 4, figure 4 means high, figure 1 low priority/importance.
  - First figure is related to costs, second figure to relevance/importance for operation of rail system based on subjective assessment of the workshop members

Task of the benchmark was a ranking of the critical S&C.

Thereby in this analysis the relevance is quantified out as an disproportionate expenditure / costs (in relation to comparable systems) and operation.

Beside the assets (components, system) also DB internal processes are key indicators for national problems.

The conclusion of the national workshop was that the project should focus on the major costs of S&C: system and maintenance.

5.2 Route Analysis

Therefore for validation and creation of a database a specific route was chosen. Both the boundary conditions have to be analysed and the annual costs and major proportions (cost drivers).

All data are based on the EDV system SAP R/3 Netz which is a maintenance database and controlling front-end of DB Netz. Within the system the infrastructure is clustered (technical place – TP) and measures are described (maintenance activity – MA). Each maintenance activity is accounted for and allocated to the TP. The TP describes an individual S&C or a track section with specific constructions / components. In dependency of the level of detail, MA could be assigned to the section or to the higher level route or station, which means e.g. an assembly of S&C. All MA are normally based on inspection results or are result of a failure (e.g. no endposition, system or component breakdown).

5.2.1 High speed line

The selected line is a high speed line with UIC 60 switches and mixed traffic with about 17,5 MGT/year (average, see figure below). The investigation period is from 01.01.2005 to 30.03.2007.

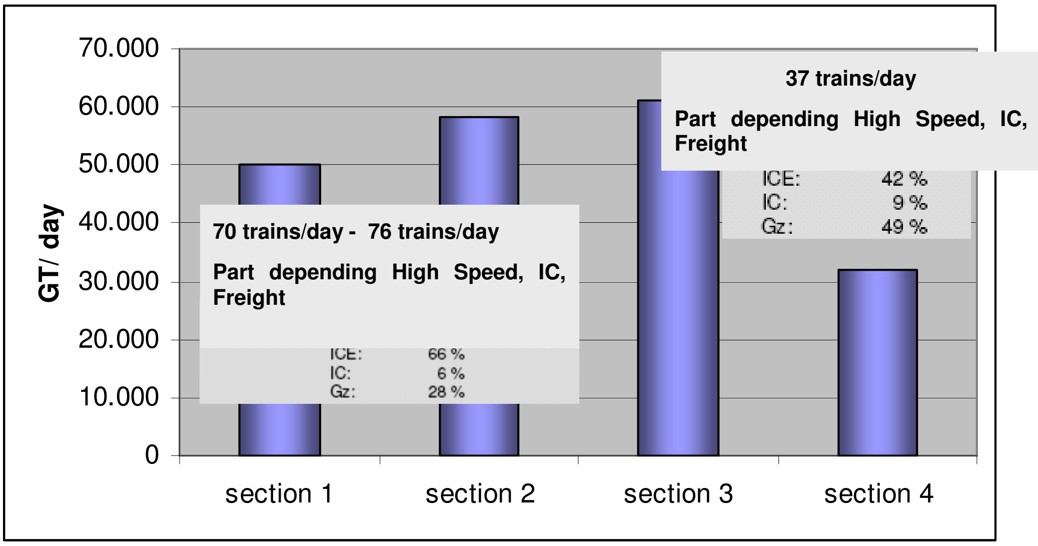


Figure 4 Traffic description for selected line

Legend for figure 4:

- ICE: InterCityExpress, maximum speed of 250 km/h, max. axle loads of 20 to
- IC: InterCity, maximum speed of 200 km/h, max. axle loads of 20 to
- Gz: freight train, maximum speed of 120 km/h, in part 160 km/h, max. axle loads of 22,5 to

The analysis of data is done in three steps:

1. Identification of the Quantity structure
2. Identification of the Accessible maintenance records
3. Analysis of costs which are allocated to specific S&C

Step 1: Quantity structure

The first step is the analysis of the selected high speed line in respect to the quantity structure of the S&Cs. This line includes 458 S&C with miscellaneous S&C types (see figure 5).

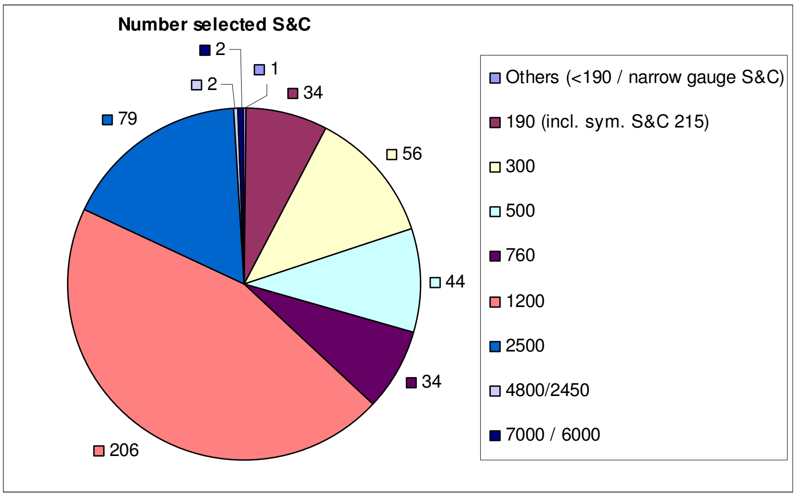


Figure 5 Number and distribution of S&C types

Step 2: Accessible maintenance records

In the second step, the accessible maintenance records of each chosen S&C were analysed. As the figure shows, only **276 S&C** contain maintenance activities; each one of the S&C had one or more recorded activities, the remaining 182 S&C didn't cause direct costs for the available data records and term.

Number S&C types	
S&C type (UIC60 - ...)	number
190 (incl. sym. S&C 215)	4
300	11
500	23
760	3
1200	163
2500	69
4800/2450	1
7000 / 6000	2
Result (accounted S&C)	276

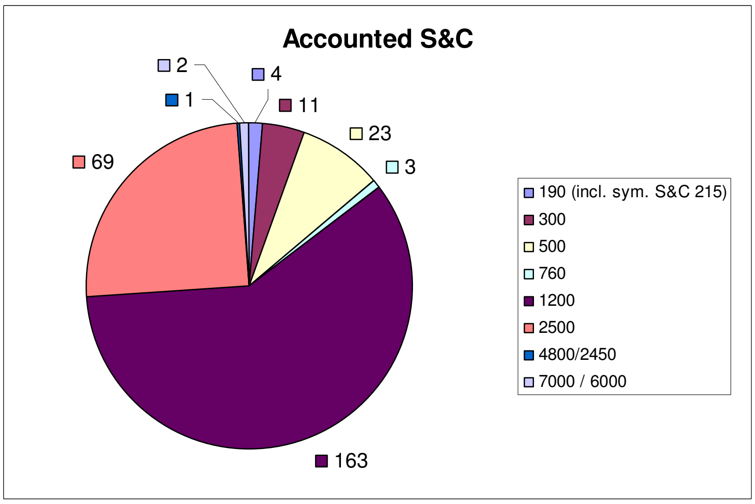


Figure 6 Number and distribution of accounted S&C

This means that not all costs are introduced by all S&C, and the costs per S&C are reduced to the analysed ones.

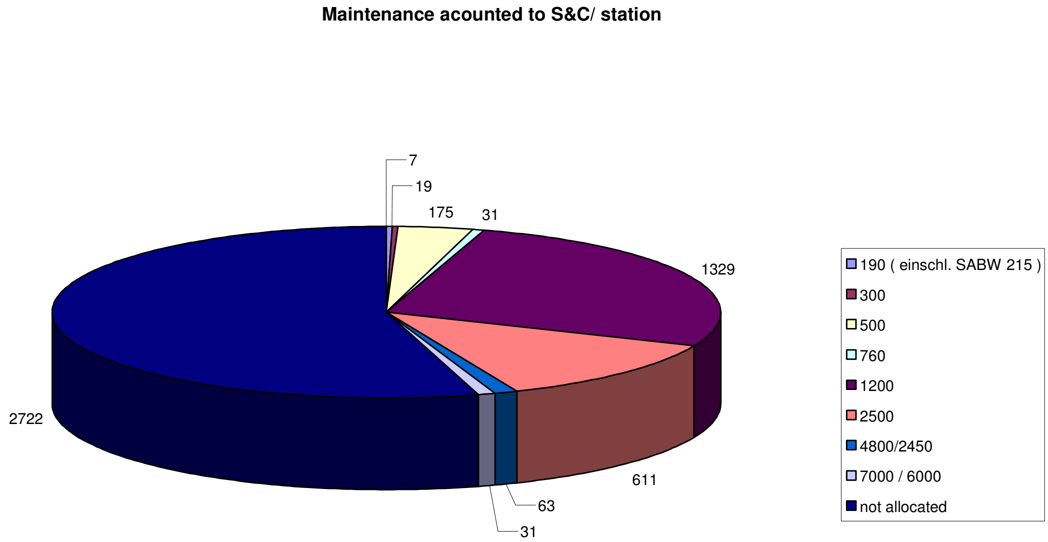


Figure 7 Distribution of maintenance records of S&C

Figure 7 shows as a first result that approx. 42% of the maintenance activities (records) are allocated to S&C. 58% (2722 records of 4988 records in total) are not allocated to specific S&C but in general to stations without dedicated allocation. These 58% of S&C maintenance records are analysed in more details in the next figure.

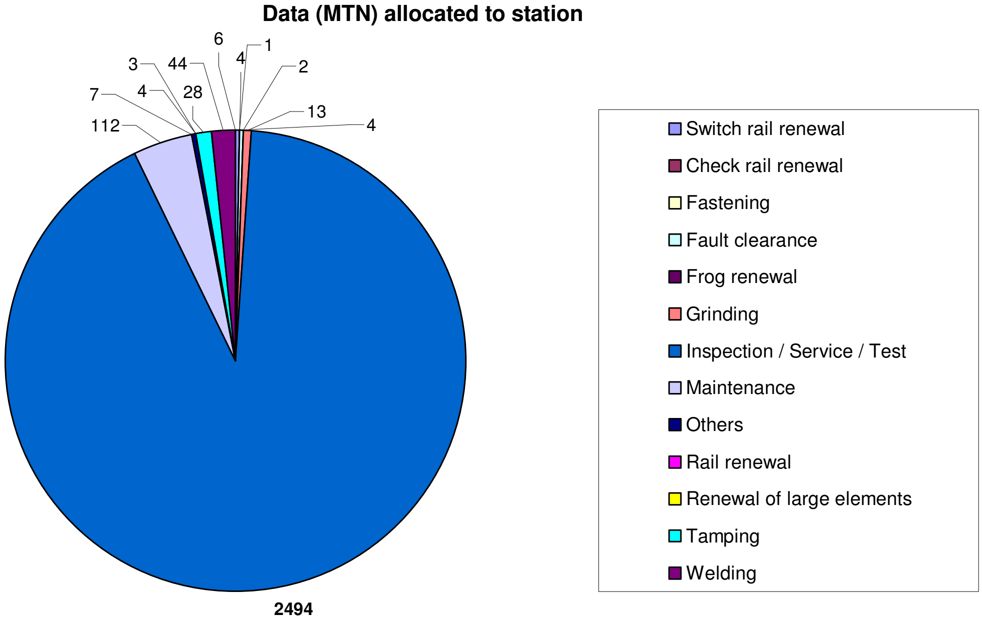


Figure 8 Number of maintenance records not allocated to any specific S&C [2]

Most cases with data not assigned to a specific S&C are general activities as shown in figure 8. These general activities can be considered as overall maintenance including service, small maintenance and tests (e.g. regular ultrasonic car).

The by far greatest portion of these general activities are inspection, service and test measures with 2494 records which is 50% of all maintenance activities (compare figure 7 with a total number of records of 4988).

Further analysis have shown that to the same time inspection, service and test measures sum up to 50% of all maintenance costs.

Step 3: Analysis of costs which are allocated to specific S&C

For the ongoing analysis, the data is analysed for the specific S&C without costs which are not allocated to specific S&C. The records of the activities are clustered by using main groups according to the table below. Costs for the main group inspection could be, e.g. small maintenance activities.

[2] Allocated to station means that the costs are not assigned to a specific S&C but to stations as they are general activities like e.g. inspection, service and test measures

MTN-acronym	Explanation	Translation	Allocation Main Group
2X	Sonstiges	Others	Others
3D	DUA Gleise	tamping (work over) rail track	Tamping
3E	DUA Weichen	tamping (work over) switches	Tamping
3F	Schienenumbau	rail reconstruction	Rail renewal
3G	Kleineisenbehandlung	fastening conditioning	Fastening
3I	kleine Instandsetzung/Unterhal	small repair	Maintenance
3O	Großteilwechsel	renewal of large elements	Renewal of large elements
3V	Neu- und Umbau Weichen	new building and reconstruction of switches	SC reconstruction/ new building
3X	Sonstiges	miscellaneous	Others
4S	Schleifarbeiten	grinding	Grinding
4T	Schweißtechnische Aufarbeitung	build-up welding	Welding
4V	Schienenverbindungsschweißen	welding of rail joint	Welding
4X	Sonstiges	miscellaneous	Others
E02	Inspekt.u.Wart. nach DIVA	inspection/ service	Inspection/ Service/ Test
E81	Inspektion GW (neu)	inspection	Inspection/ Service/ Test
EMI	Inst. elektr. Energieanl. DB N	Maintenance elect. Power	Maintenance
ENT	Entstörung	fault clearance	Fault clearance
GAS	GL schweißtech.Aufarb. m Gleis	build-up welding (track)	Welding
GGT	Gl Großteilewechsel	renewal of large elements	renewal of large elements
GSI	GL Schienenumbau m Strang	rail renewal (stratch of rail)	Rail renewal
GSW	GL Schwellenumbau m Gleis	sleeper reconstruction (track)	Sleeper renewal
I01		inspection	Inspection/ Service/ Test
I02		inspection	Inspection/ Service/ Test
I40	Insp.BL nach 89201 (40)	inspection	Inspection/ Service/ Test
I70	Insp.Gleisbegehung	inspection	Inspection/ Service/ Test
I77	Ultraschallmessung SPG	test	Inspection/ Service/ Test
I79	Schienenoberflächenmessung	test	Inspection/ Service/ Test
I87	Insp.Fahrbahn SA in Gleisen	inspection	Inspection/ Service/ Test
IEB	EBA-Inspektionen	Inspection	Inspection/ Service/ Test
INL	Inspekt. Notlaschenverbindung	inspection	Inspection/ Service/ Test
INS	Instandsetzung	Maintenance	Maintenance
ISE	Son-Insp.Terminüberschreitung	inspection	Inspection/ Service/ Test
ISI	Sonderinspektion	inspection	Inspection/ Service/ Test
IXX	xxx	xxx	Others
K48	xxx	xxx	Others
LSG	Instands. Gleis-Schaltm. Freim	Maintenance	Maintenance
LSK	Instands. Kabelanlagen	Maintenance	Maintenance
LSZ	Instands. ZUB-Einrichtungen	Maintenance	Maintenance
LVE	Instands. Vermasch.-Erdung	Maintenance	Maintenance
LWE	Inst.el.Bauteile WK / GSP	maintanance of el. components SC	Maintenance
LWM	Inst.mech.Bauteile WK	maintanance of mech. components SC	Maintenance
N01	Nachhaltigkeit	Miscellaneous	Others
OLI	Instandsetzung OI	maintenance	Maintenance
OLR	Inst. Erdung & Triebstromrückf	maintenance	Maintenance
PKI	KLI Sonst.planbare Kl.Inst.	small maintenance	Maintenance
PLA	aktivierbare Planungsleistung	activatable planning activity	Planning
SP	Spezialtrupp Großteilwechsel	stuff renewal of large elements	Renewal of large elements
W01		inspection/ service	Inspection/ Service/ Test
W03		inspection/ service	Inspection/ Service/ Test
W20	Bes.,Rei.u.Sch.WK n.8929302_91	inspection/ service	Inspection/ Service/ Test
W21	Bes.,Rei.u.Sch.WK n.8929302_92	inspection/ service	Inspection/ Service/ Test
W22	Bes.,Rei.u.Sch.WK n.8929302_93	inspection/ service	Inspection/ Service/ Test
W24	Bes.WE R=>1200m m.v=>200km/h	inspection/ service	Inspection/ Service/ Test
W31	LST-Insp.u.Wart.a.Gleissperren	inspection/ service	Inspection/ Service/ Test
W60	Insp. u. Wart. WK PRINS	inspection/ service	Inspection/ Service/ Test
W61	Insp. u. Wart. WK ALV u. TL	inspection/ service	Inspection/ Service/ Test
W62	Schmieren u. Reinigen WK	inspection/ service	Inspection/ Service/ Test
W63	Bes. WE R=>1200m m.v=>200km/h	inspection/ service	Inspection/ Service/ Test
W81	I+Wart. RSTW	inspection/ service	Inspection/ Service/ Test
WAS	WK schweißtech.Aufarb. Stück	SC build-up welding (unit)	Welding
WDZ	WK DUA masch + Zarb Stück	SC machined tamping	Tamping
WGT	WK Großteilewechsel	SC renewal og large elements	Renewal of large elements
WHZ	Herzstückwechsel	SC frog renewal	Frog renewal
WRL	Radlenkerwechsel	SC check rail renewal	Check rail renewal
WSI	WK Schienenumbau kompl. Stück	SC rail renewal (unit)	Rail renewal
WSS	WK Sch.schleifen masch Stück	SC machined rail grinding (unit)	Grinding
WSW	WK Schwellenumbau Stück	SC sleeper reconstruction (sleeper set)	Sleeper renewal
WZV	Zungenvorrichtung wechseln	Renewal half set of switches	Renewal half set of switches
999	xxx	others	Others

Table 1 Allocation activities to main groups (Cluster)

The figure below shows the allocation to the main groups taking the S&C type into account.

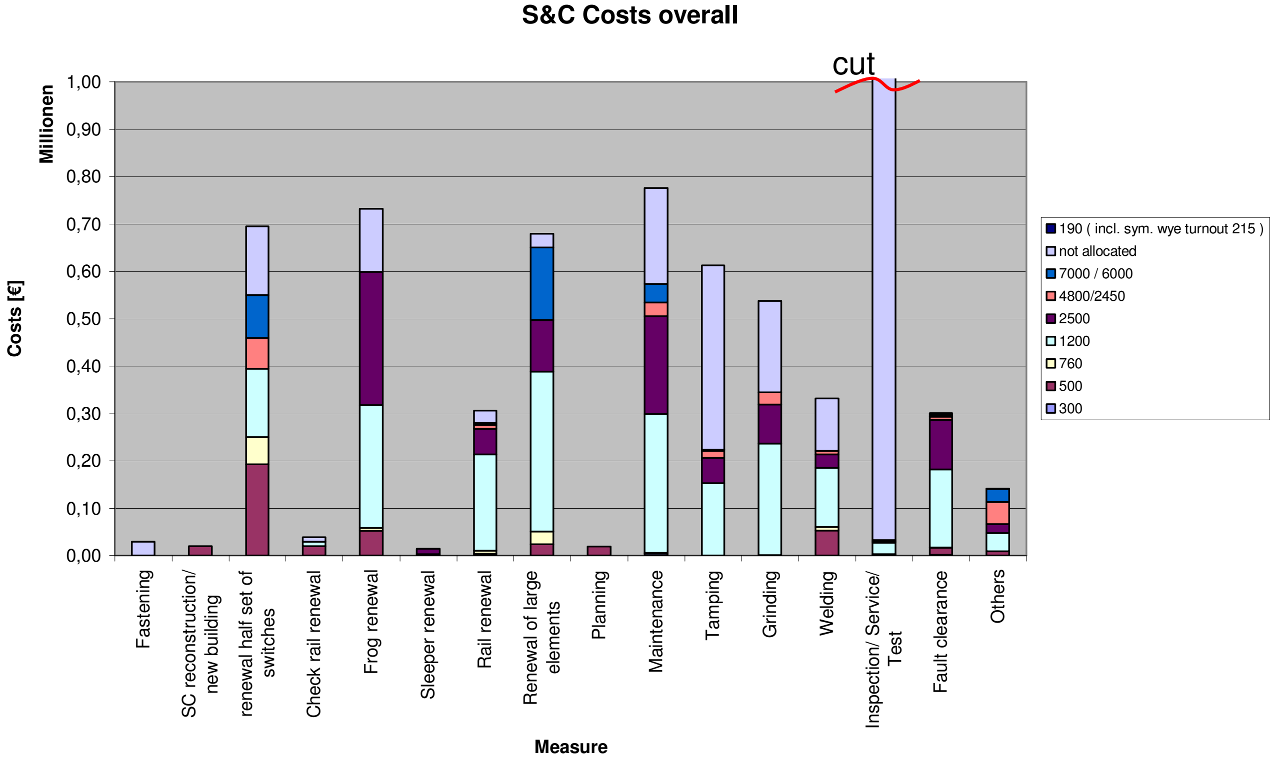


Figure 9 Accounting allocation to S&C and station (not allocated to specific S&C)

Figure 9 shows that beside the bar inspection/service/test the main cost factors are caused by maintenance (according to table 1 this is corrective maintenance), frog renewal, switch rail renewal (half set) and renewal of large elements followed by tamping and grinding. Compared to this main cost factors it's also shown that measures for fastenings, check rail renewal, sleeper renewal and planning do not cause significant costs.

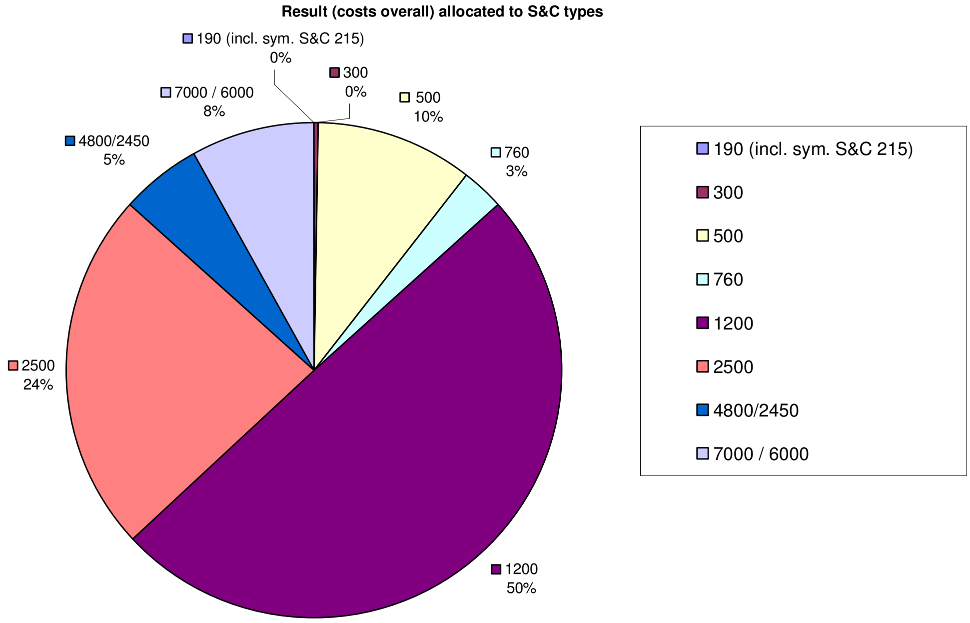


Figure 10 Resulting overall S&C costs categorised by S&C types (incl. maintenance, inspection/service/test)

As a result it was found that e.g. 50% of the costs are caused by S&C type UIC60-1200, which are also approx. 50% of the chosen S&C. The top scorers with respect to costs are the S&Cs as shown in the table below. These have to be analysed more in detail. According to the number of records related to a unique S&C the range is between 70 and 1 record(s) per S&C.

Specific S&C (unique name)	Radius curve S&C	Number records	S&C	percentage
		2.259		costs
WE1 |EWL-60-4800/2450-1:26,5fb-B	4800/2450	63	1	**5,20%**
WE810 |EWL-60-7000/6000-1:42-fb-B	7000 / 6000	14	2	4,65%
WE210 |EWR-60-2500-1:26,5-B fb	2500	70	3	3,52%
WE806 |EWR-60-7000/6000-1:42-fb-B	7000 / 6000	17	4	3,35%
WE1 |EWL-60-1200-1:18,5-B fb	1200	10	5	3,15%
WE22 |EWR-60-1200-1:18,5-B fb	1200	28	6	2,78%
WE121 |EWL-60-1200-1:18,5-B fb	1200	22	7	2,41%
WE543 |EWR-60-2500-1:26,5fb-B	2500	9	8	2,28%
WE151 |EWR-60-2500-1:26,5fb-B	2500	32	9	1,94%
WE102 |EWR-60-2500-1:26,5fb-B	2500	11	10	1,89%

Table 2 Top 10 scoring S&C

For further analysis it is necessary to identify the costs factors of the S&C related to the components – if possible – and assess the different costs factors with respect to the S&C type, as it depends on this property.

The analysis of costs per unit S&C (total costs) has shown that the most cost driving S&C (cf. Table 2 Top 10 scoring S&C) are the S&C types UIC60-4800/2450 and UIC60-7000/6000. Because this types of S&C are not representative (only 4 of 458 chosen S&Cs, see figure 5) they are unimportant for a representative analysis.

Next to this was to put also the geometrical length (Table 3) of the S&C into the analysis, to see the differences (cp. Figure 11).

S&C type (UIC60-...)	Mean lenght in m
190 (incl. sym. S&C 215)	27,14
300	33,23
500	43,22
760	54,22
1200	66,55
2500	94,31
4800/2450	94,31
7000 / 6000	154,27

Table 3 S&C types, mean geometrical length

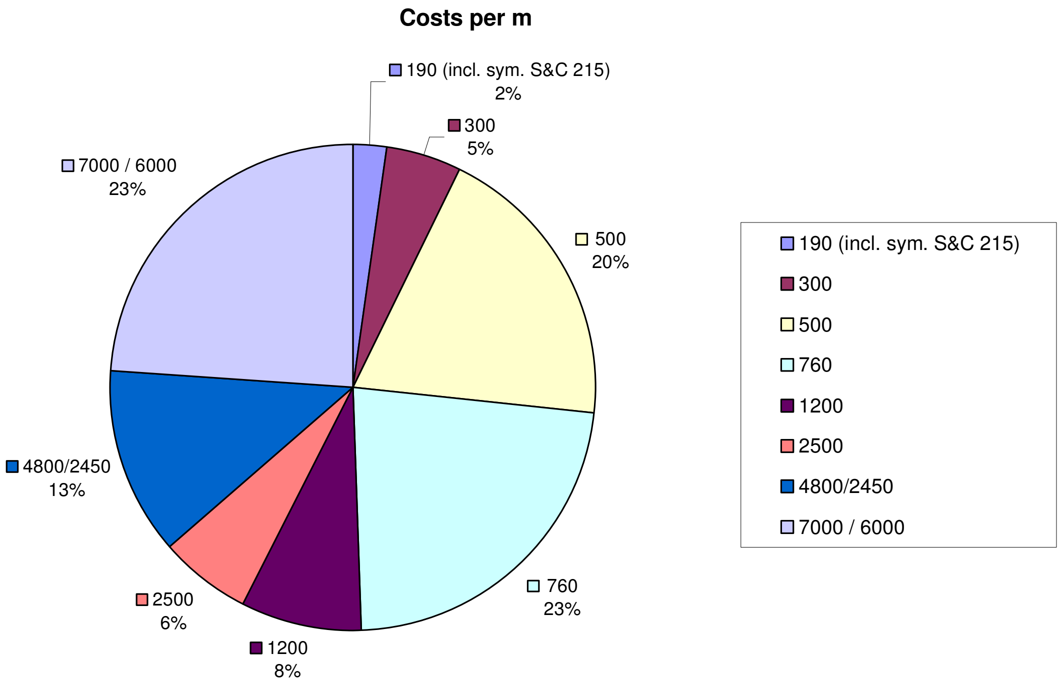
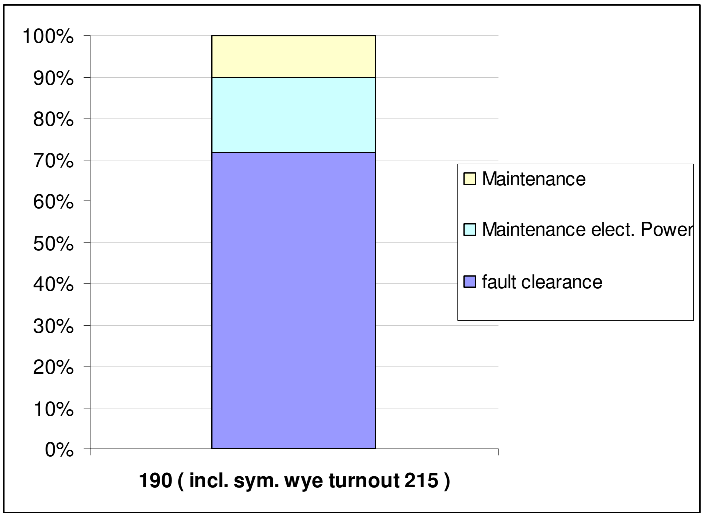
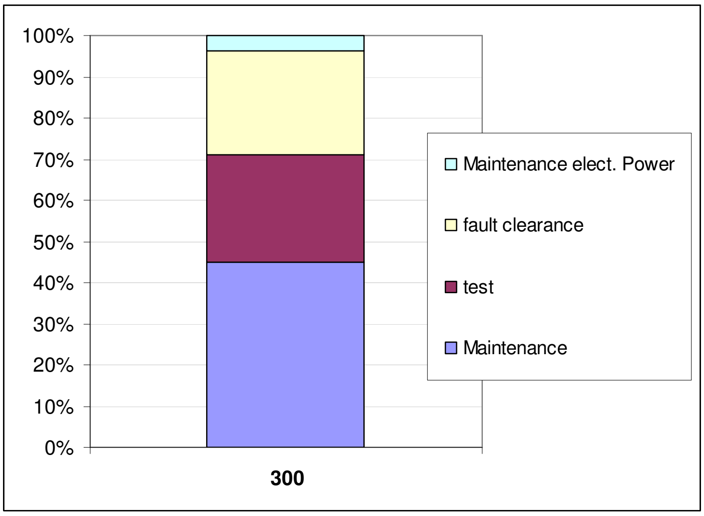


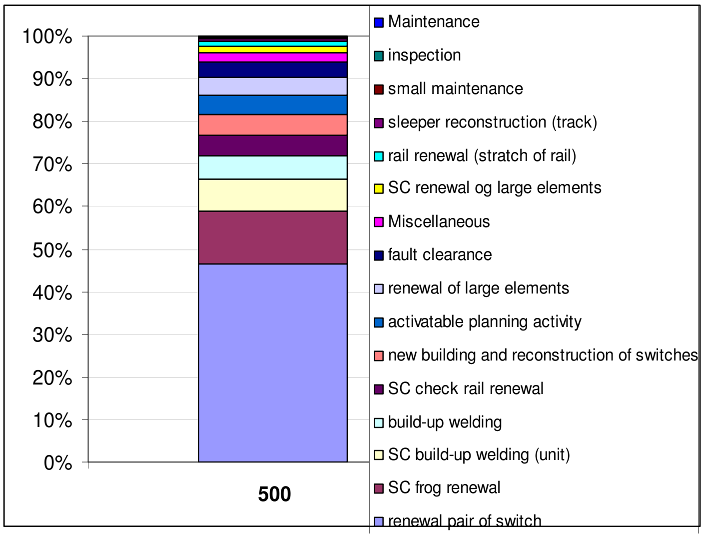
Figure 11 Costs per m (geometrical length) S&C

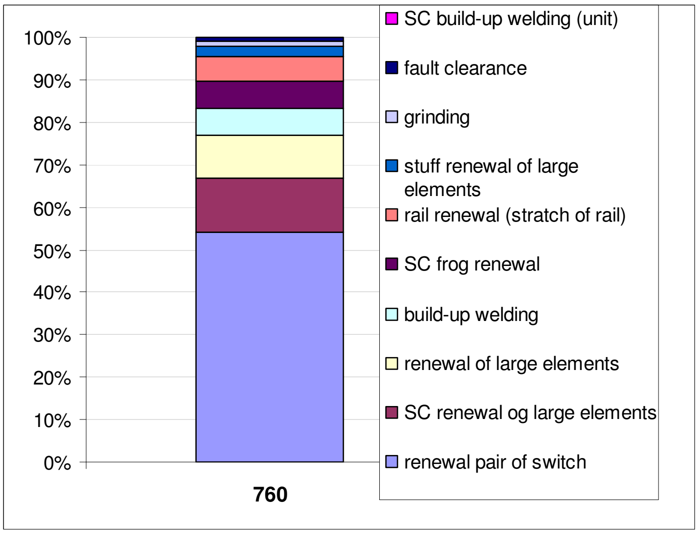
If the geometrical length of the S&C is considered and only direct costs are accounted for, the main cost factor per meter S&C are those of S&C type UIC60-760 together with UIC60-7000/ 6000 with 23%. These are followed by UIC60-500 (20%) etc. The costs drivers are not identical per unit and per meter S&C. The analysis of costs per meter S&C could be of interest for other examinations. Therefore they are part of this report.

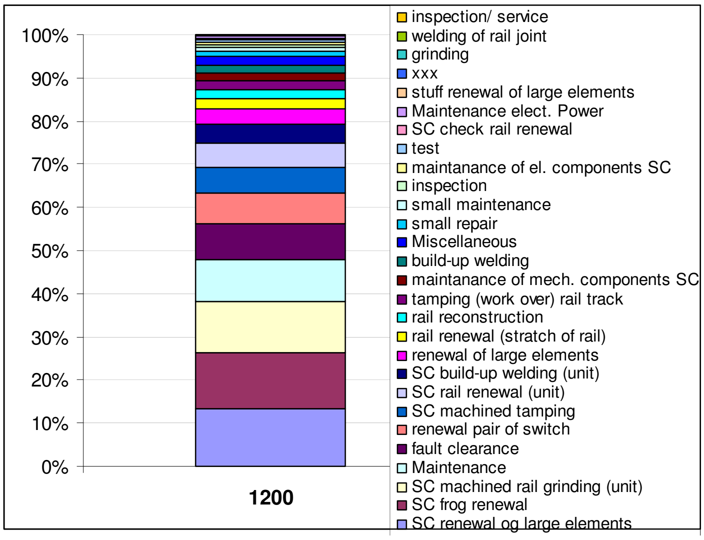
The following analyses however are based on costs per unit S&C.

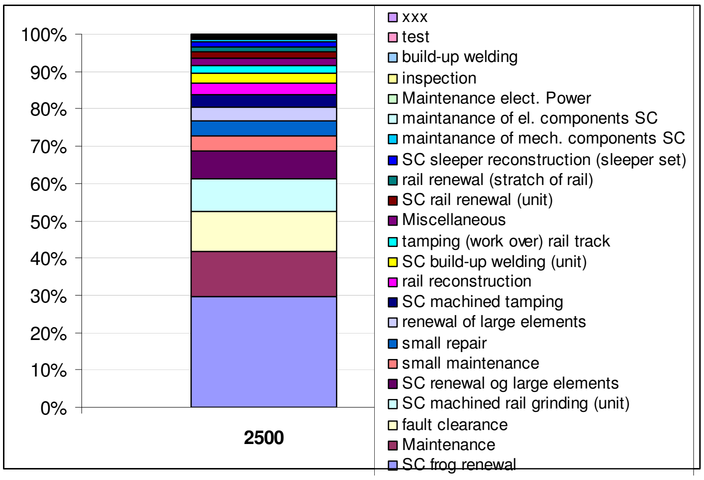

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Maintenance
Maintenance elect. Power
fault clearance
190 (incl. sym. wye turnout 215)


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Maintenance elect. Power
fault clearance
test
Maintenance
300


Maintenance
inspection
small maintenance
sleeper reconstruction (track)
rail renewal (stratch of rail)
SC renewal og large elements
Miscellaneous
fault clearance
renewal of large elements
activatable planning activity
new building and reconstruction of switches
SC check rail renewal
build-up welding
SC build-up welding (unit)
SC frog renewal
renewal pair of switch
500


SC build-up welding (unit)
fault clearance
grinding
stuff renewal of large elements
rail renewal (stratch of rail)
SC frog renewal
build-up welding
renewal of large elements
SC renewal og large elements
renewal pair of switch
760


inspection/ service
welding of rail joint
grinding
xxx
stuff renewal of large elements
Maintenance elect. Power
SC check rail renewal
test
maintanance of el. components SC
inspection
small maintenance
small repair
Miscellaneous
build-up welding
maintanance of mech. components SC
tamping (work over) rail track
rail reconstruction
rail renewal (stratch of rail)
renewal of large elements
SC build-up welding (unit)
SC rail renewal (unit)
SC machined tamping
renewal pair of switch
fault clearance
Maintenance
SC machined rail grinding (unit)
SC frog renewal
SC renewal og large elements
1200


xxx
test
build-up welding
inspection
Maintenance elect. Power
maintanance of el. components SC
maintanance of mech. components SC
SC sleeper reconstruction (sleeper set)
rail renewal (stratch of rail)
SC rail renewal (unit)
Miscellaneous
tamping (work over) rail track
SC build-up welding (unit)
rail reconstruction
SC machined tamping
renewal of large elements
small repair
small maintenance
SC renewal og large elements
SC machined rail grinding (unit)
fault clearance
Maintenance
SC frog renewal
2500

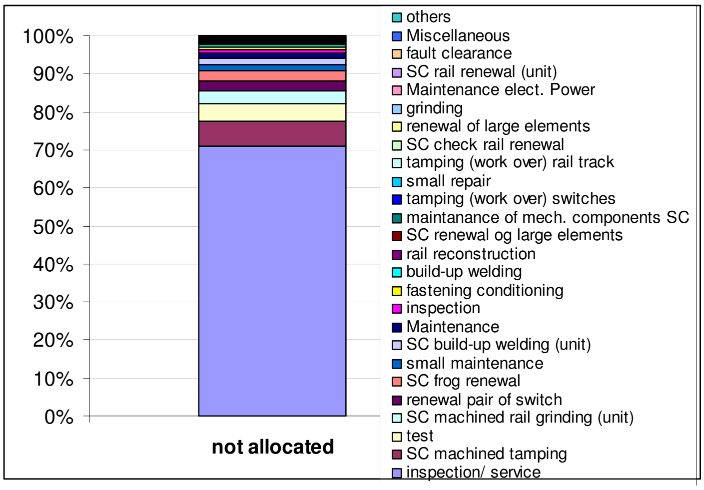


Figure 12 Distribution of costs according to S&C types [3]

The costs shown above are 100% full costs for each specific S&C type. In comparison to figure 9, figure 12 shows the detailed diagrams of the costs for each specific S&C type.

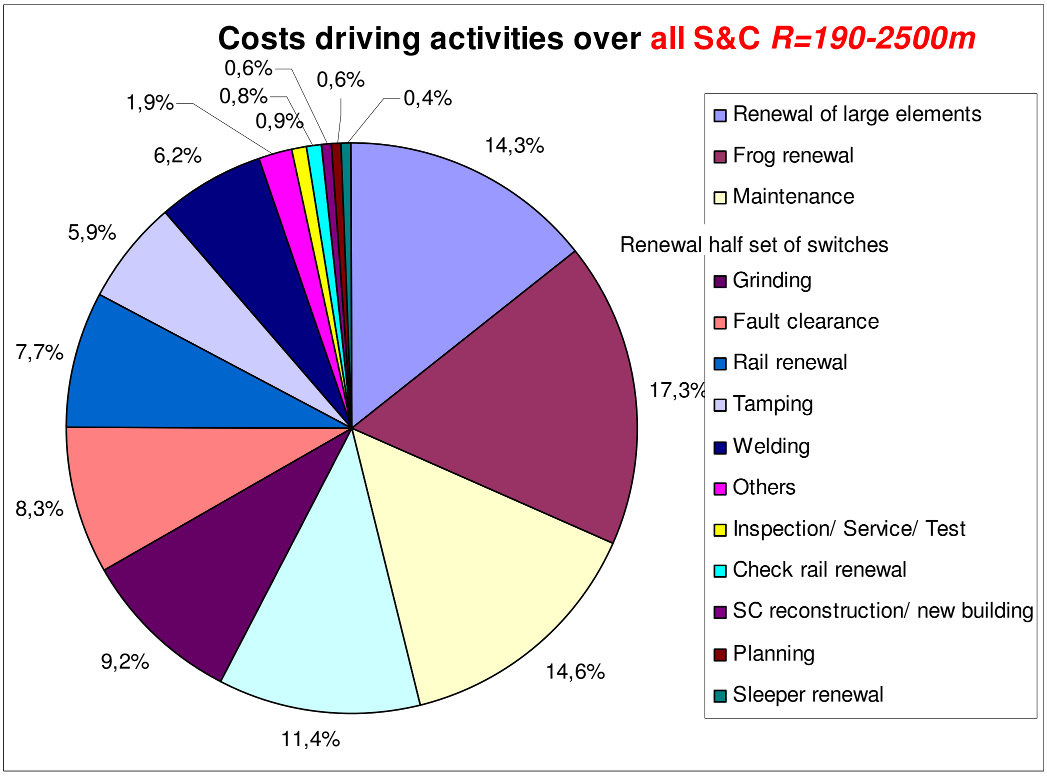


Figure 13 Cost driving MTN-activities over all costs and S&C types with R = 190 – 2500m

DB spends most money for the frog renewal, second for maintenance incl. small repair, third for renewal of large elements and forth for switch rail renewal (half set).

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[3] In fig. 12 'renewal pair of switches' is meant as 'renewal half set of switch'.

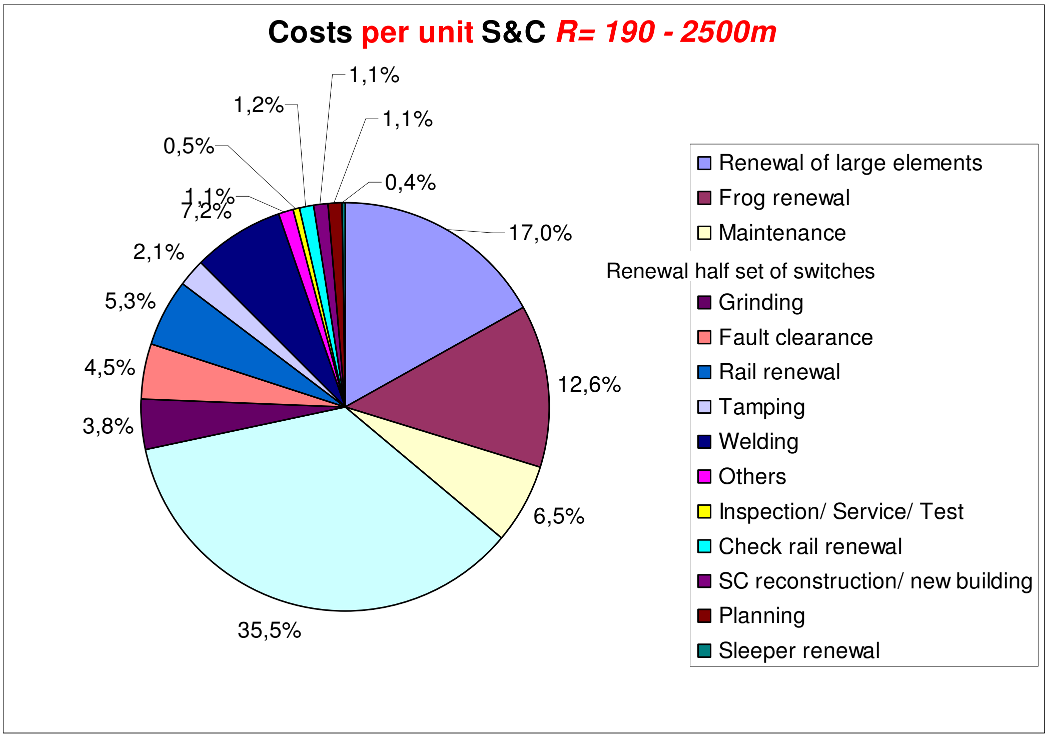

Figure 14 Cost driving MTN-activities over all costs and S&C types per unit reduced to R = 190 – 2500m

The figure above is based on the 276 S&C which caused maintenance activities (see. figure 6).

This analysis shows that the major cost factors are

- **renewal of switch rails (half set) with about 35%,**
- **large elements (these are not separated between frogs or switch rails etc.) with 17% and**
- **frog renewal with about 13%.**

All together this is an amount of 65% of the costs per S&C while the other activities like welding, maintenance (e.g. minimal repair), tamping etc. sum up to “only” 35% on the selected line.

This analysis has also shown that approx. 42% of the overall costs for all 458 chosen S&Cs are allocated to the specific S&C, 58% are not allocated. The latter costs contain costs for inspection, service and test measures.

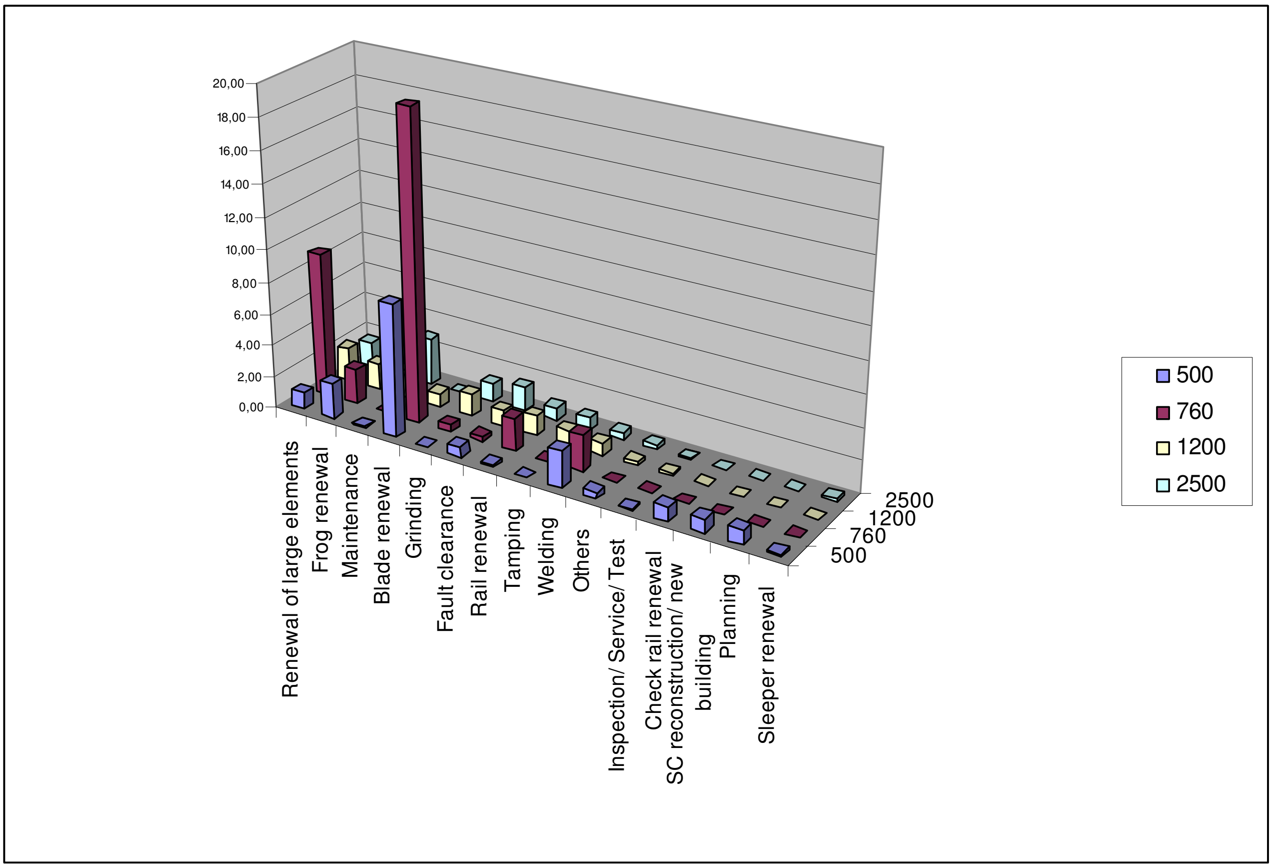

Figure 15 Costs per S&C distributed to S&C type [4]

[4] without inspection / test / service. In fig. 15 'Blade renewal' is meant as 'Renewal half set of switch'.

The figure above shows the costs for the different activities allocated to the most important types of S&Cs.

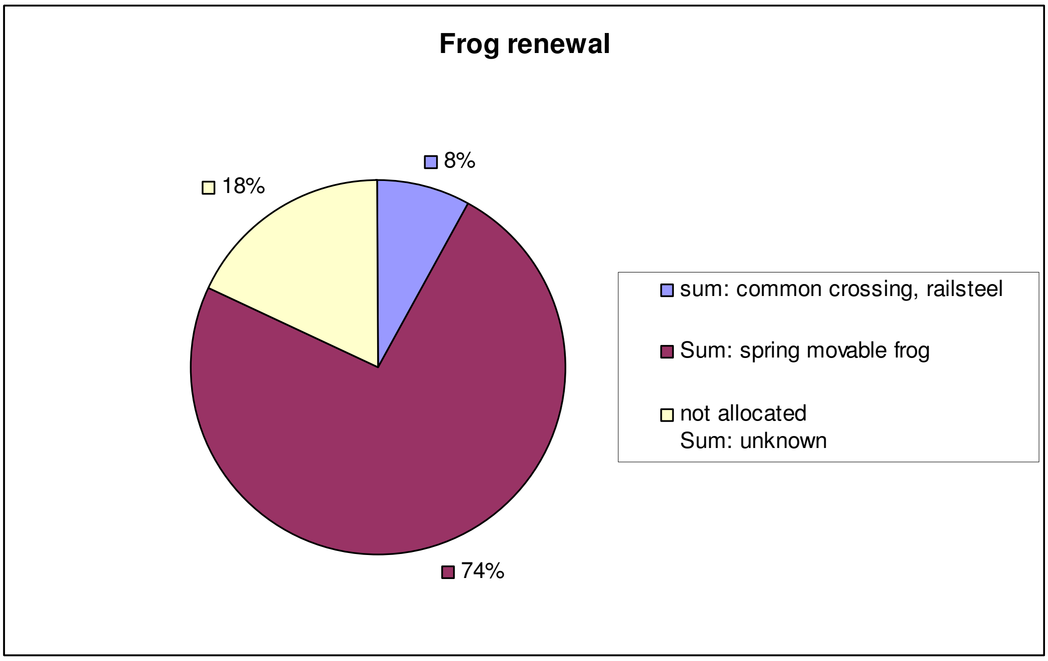

Figure 16 Distribution frog renewals over construction (fixed frog, moveable frog)

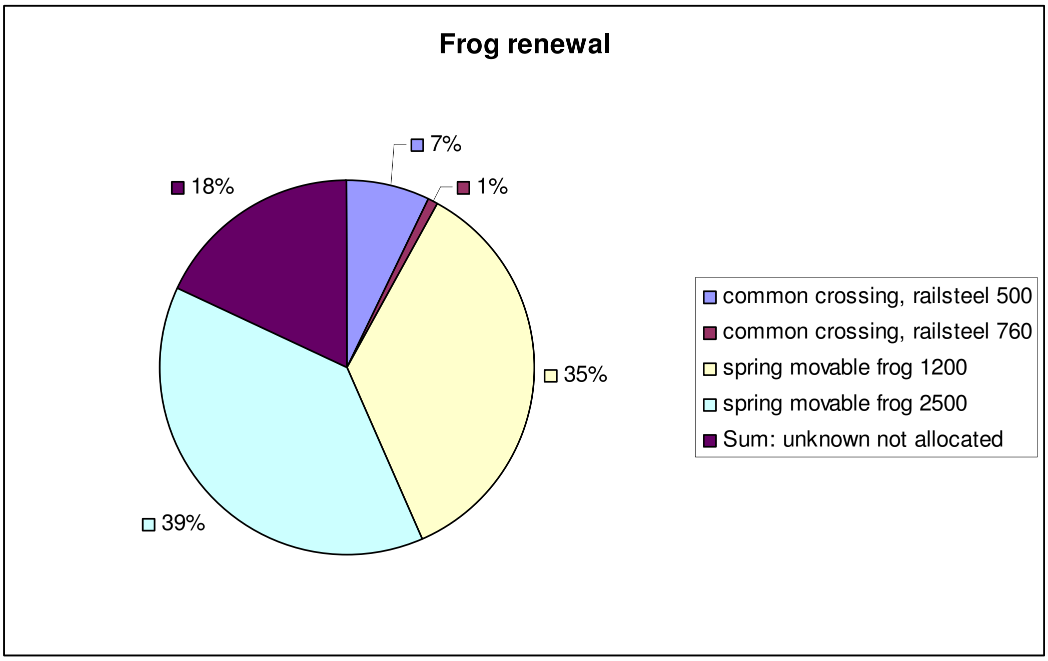

Figure 17 Distribution frog renewals over construction incl. S&C type

Both figures above show the proportion of total costs for frog renewal on the selected line depending on the type of frog (moveable / fixed (not moveable)). S&Cs of type UIC60-500 are always equipped with fixed frogs while those of type UIC60-760 are often and of type UIC60-1200 and -2500 are always equipped with moveable frogs.

Both figures give an impression that in evidence the costs for renewal of moveable frogs are higher than this for fixed frogs.

5.2.2 Others

The first results from other analyses show that the costs for renewal of switch rails are about the same as for frogs. This has to be taken into account when interpreting the results of the selected line in chapter 5.2.1.

Follow-up analyses for other routes with different characteristics are under way.

5.3 Resulting cost drivers of DB

In this chapter the identified questions and issues are summarized.

The results of the workshop are separated in technical problems and best practises. In the case of best practises the IM mainly asked for the experiences, approaches or limit values of other railway companies.

The analysis of the selected high speed line with UIC 60 S&Cs and mixed traffic with about 17,5 MGT/year (average) has shown that approx. 42% of the overall costs for all 458 chosen S&Cs are allocated to the specific S&C, 58% are not allocated, but contain a high proportion (50%) of inspection, service and test measures. These costs are thus the majority for the selected DB line.

The analysis shows further on that the main cost factors (without inspection/service/test) are

- renewal of switch rails (half set) with about 35%,
- large elements (these costs are not separated between frogs or switch rails etc.) with 17% and
- frog renewal with about 13%.

All together this increases to 65% of the costs per unit S&C while other activities like welding, maintenance, tamping etc. “only” sum up to 35% on the selected line.

Results from another DB analysis confirm the presented conclusions in general, but show that the costs for renewal of switch rails and frogs are roughly equal.

6. Cost factors BV

6.1 Overview maintenance cost for S&C on dedicated lines

General

Three different Swedish lines have been studied:

- Western Main Line (Laxå – Partille) 216 km double track.
- Iron Ore Line (Boden-Luleå and Kiruna – Riksgränsen) 160 km single track
- Southern Main Line (Hässleholm-Höör) (The study is not yet finished)

The cost estimation made here is not complete in the sense that only the following costs have been included

- Failure and repair
- Predetermined maintenance + inspections
- Action after inspections
- Tamping
- Grinding

The following costs have not been included

- Damage (for instance derailment and sabotage)
- Tempering (to neutralise the track to a stress free temperature)
- Snow clearance
- Heating of S&C

The sources of data have been the cost database – "Agresso", the failure database – "0felia", the inspection database – "Bessy" and the asset management database – "BIS".

The cost data has been distributed down to station - station lines. The cost database is storing cost for maintenance and reinvestment separately. As there is no clear acceptance as to what to denote maintenance and what to be considered as reinvestment when taking decision on action to retain and restore the infrastructure it is not possible to compare the different lines by using this data. The comparison made here is more to clarify which type of action that is needed to keep a good standard of the asset. Also the study is intended to give answers as to what causes more intense actions as compared to the part of the line that needs less actions.

Traffic

Line	Track section nr	Track section	Passenger train/day	Freight train/day	Totalt	Million Gross Ton/Year (assumed)
Iron Ore	111	Riksgränsen-Kiruna C	4	27	31	20,6
Iron Ore	119	Luleå-Boden	10	31	41	18,0
Western Main	512	Laxå-Skövde	63/58	50/48	113/106	8,3
Western Main	512	Skövde-Falköping	92	41	133	8,3
Western Main	611	Falköping-Alingsås	60	44/46	104/106	8
Western Main	612	Alingsås-Partille	143	46	189	9,2
Southern Main	910	Hässleholm-Höör	73	63	136	10,3

Table 4 Traffic description (as stated in "Nulägesbeskrining 2001")

Result S&C

	EV-SJ50-11-1:9		EV-UIC60-760-1:9		EV-UIC60-760-1:15	
Track section	**Nr**	**Cost per S&C**	**Nr**	**Cost per S&C**	**Nr**	**Cost per S&C**
111 Riksgränsen-Kiruna C	10	20 100	7	25 400	8	18 500
119 Luleå-Boden			8	12 000	5	12 200
512 Laxå-Falköping	14	EV-SJ50-12-1:15 9 500	2	9 100	28	7 400
611 Falköping-Alingsås	1	13 900	3	8 900	10	9 200
612 Alingsås-Partille	7	9 100	1	10 700	6	6 700

Table 5 Cost for maintaining different types of S&Cs

The highest cost for maintaining S&Cs are on the track section 111 in the northern part of Sweden. Cold weather and high axle load (25 metric tonnes) are factors that can be involved. The cost for different S&C type have been compared by using the cost per MGT, which makes it possible to compare track sections with different amount of traffic, as in figure 18.

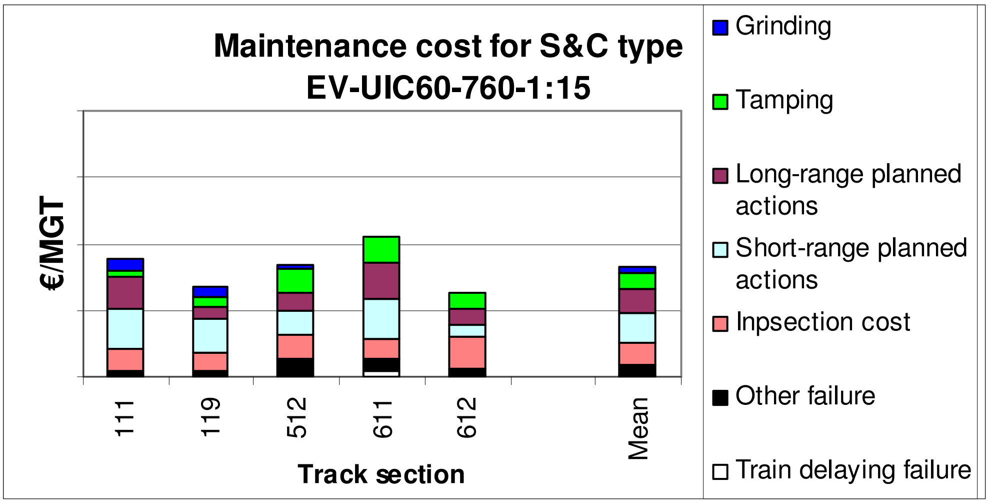

Figure 18 Cost for one type of S&C on different track sections *(definition of long-range and short-range planned actions see Glossary)*

The cost for newer S&C can be assumed to be lower than for older S&C-types. Figure 19 shows such a comparison, but as the number of S&C of a certain type is different on each track section, this conclusion is not very clear, see also table 5.

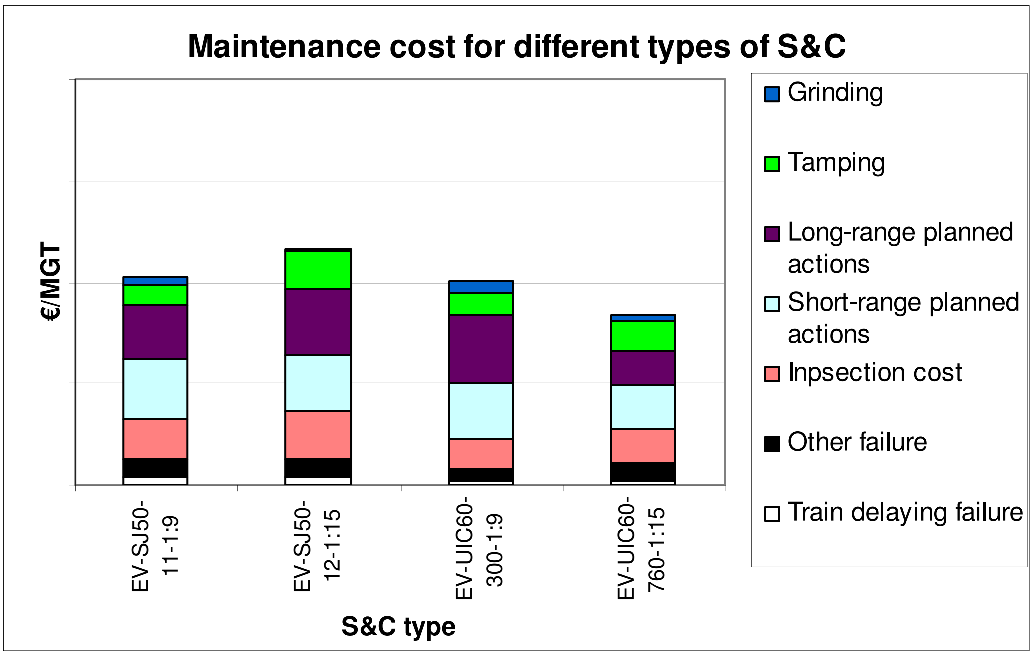

Figure 19 Average cost for different types of S&C's

6.2 Report on cost for S&C on the Swedish line 119

General

The chosen line is number 119 between Boden – Luleå. It is a mixed traffic line with many freight trains (see table 4). The highest axle load is 30 metric tonnes and the traffic is estimated to be 20 MGT/year (Million Gross Tonnes per year).

The line is 33 km long and has 5 meeting stations. There are 13 S&Cs in main track and 21 S&Cs in side track. The S&Cs with associated cost are:

S&C	Type	Rail type	Radius	Installed year	Main track	Assumed Maintenance cost k€/year	Assumed Train delay cost k€/year
gst-gst 6	SJ43-5,9-1:9	43	*		No	1,9	0
gst-gst 8	SJ43-5,9-1:9	43	*		No	1,4	0
gst-gst 16	BV50-225/190-1:9	50	*	2003	No	1,3	3,2
gst-gst 17	BV50-225/190-1:9	50	*	2003	No	1,4	0
gst-gst 18	BV50-225/190-1:9	50	*	2003	No	0,5	0
gst-gst 12b	SJ50-11-1:9	50	300	1967	No	0,8	0
gst-gst 14b	UIC60-300-1:9	60	300	2003	No	3,1	0
gst-gst 17a	BV50-225/190-1:9	50	*		No	0,9	0,1
gst-gst 18a	BV50-225/190-1:9	50	*		No	1,1	0
gst-gst 2b	BV50-225/190-1:9	50	*	2003	No	1,8	0
gst-gst 3a	BV50-225/190-1:9	50	*	2003	No	1,1	0
gst-gst 3b	BV50-225/190-1:9	50	*		No	1,7	0
gst-gst 5b	SJ50-11-1:9	50	300	1969	No	0,5	0
nvn-nvn 16	SJ41-5,9-1:9	41	*		No	1,1	0
nvn-nvn 2b	SJ41-5,9-1:9	41	*		No	1,2	0
nvn-nvn 3b	SJ50-11-1:9	50	300		No	0,5	0
nvn-nvn 7a	SJ50-11-1:9	50	300		No	2,5	0,1
nvn-nvn 7b	SJ50-5,9-1:9	50	*	1965	No	3,2	0
sby-sby 2	SJ50-11-1:9	50	300		No	4,6	0
svt-svt 3	SJ50-11-1:9	50	300	1990	No	0,7	0
svt-svt 6	SJ50-12-1:12	50	500	1979	No	2,3	0
gst-gst 1	UIC60-300-1:9	60	300	1987	Yes	14,6	25
gst-gst 13	UIC60-300-1:9	60	300	1995	Yes	10,5	1,3
gst-gst 14a	UIC60-300-1:9	60	300	1995	Yes	8,3	1,6
gst-gst 2a	UIC60-300-1:9	60	300	1987	Yes	16,4	15,1
nvn-nvn 1	UIC60-300-1:9	60	300	1996	Yes	12,6	0,1
nvn-nvn 8	UIC60-300-1:9	60	300	1995	Yes	11	0
nvn-nvn 9a	UIC60-300-1:9	60	300	1994	Yes	10,7	0

S&C	Type	Rail type	Radius	Installed year	Main track	Assumed Maintenance cost k€/year	Assumed Train delay cost k€/year
sby-sby 1	UIC60-760-1:15	60	760	1996	Yes	15,3	0,4
sby-sby 6	UIC60-760-1:15	60	760	1996	Yes	14,1	0
sus-sus 1	UIC60-760-1:15	60	760	1999	Yes	11,4	1,1
sus-sus 2	UIC60-760-1:15	60	760	1999	Yes	7,7	1,4
svt-svt 1	UIC60-300-1:9	60	760	1994	Yes	14,6	0,4
svt-svt 7	UIC60-760-1:15	60	760	1994	Yes	14,1	0

Table 6 S&Cs on line 119 [5]
*(deviation angle: see specification 1:9, 1:15 etc. in column 'type'; *: to be checked later)*

An analysis of table 6 shows that on main track the maintenance costs per unit UIC60-300 and UIC60-760 are about the same while the maintenance costs per unit on main track are about 8 times higher than on side track.

Data sources

The data available for this report have been cost data for the years 2004-2006. failure data for 2004-2006, inspection report for 2005-2006 as well as tamping and grinding data from between 1999-2006.

The cost data for the year 2004 was more specified and therefore it is possible to calculate a unit cost for certain maintenance action as for instance switch tamping.

The calculation is based on several assumptions, such that all failures have the same cost. In the same manner the inspection cost is divided into the category short- and long-range planned actions which also are given unit costs. These assumptions are coarse but give a first estimate to find cost factors. Unit cost has been calculated by dividing the failure or inspection cost with the associated number of failure and inspection activities respectively.

Other costs have been estimated in other ways as

Inspection cost, S&C	635 Euro/S&C
Grinding, S&C	4890 Euro/S&C
Tamping, S&C	3260 Euro/S&C
(Train delay cost	54 Euro/min)

Maintenance cost for S&C

The cost for S&C is presented per turnout.

Figure 20 shows the cost for all S&Cs. The dominating cost is for the S&Cs in main track. Before this investigation it was believed that the maintenance cost was around 7 000 € /year. The cost seems to be at least 50% higher than this on the studied line. There are some S&Cs associated with higher costs than others. This might not be true because the number of registered actions are few and random factors might play a role in the actual distribution. Further analysis is required. What is known from previous investigation is that factors influencing failure and inspection remarks are for instance

- Traffic (use of deviating track, main direction of traffic)
- Placing of S&C (close to bridges and curves)
- Climate (Snow and ice)

[5] BV uses BV50 in current standard but BV = Banverket was earlier SJ (the train operator) and therefor SJ50 is the same rail profile (50 kg/m) as BV50.

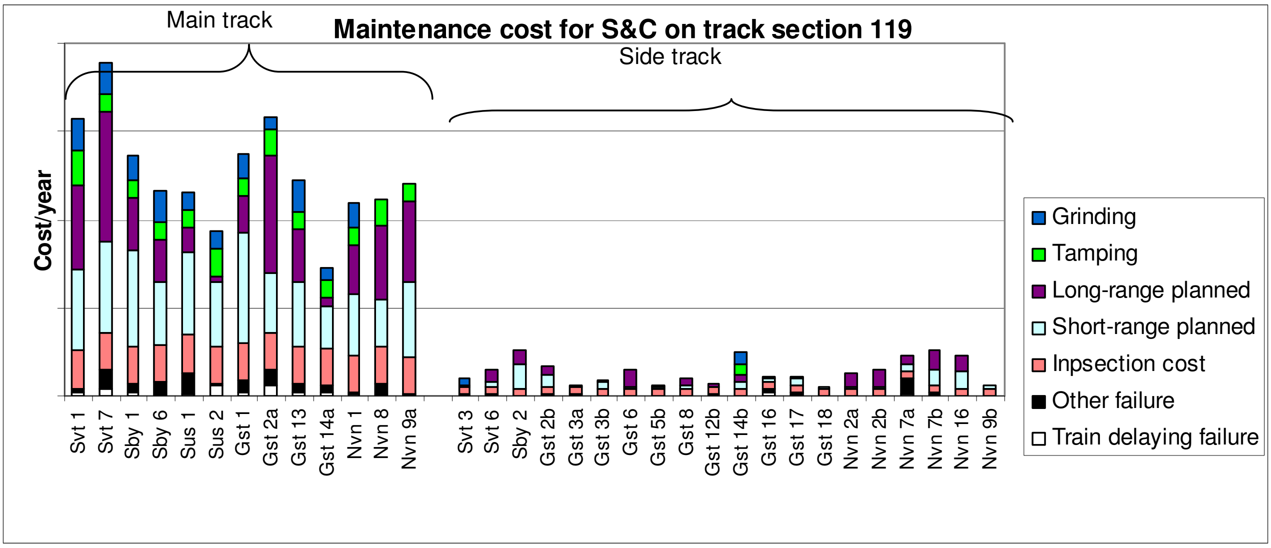

Figure 20 Cost for individual S&C on line 119

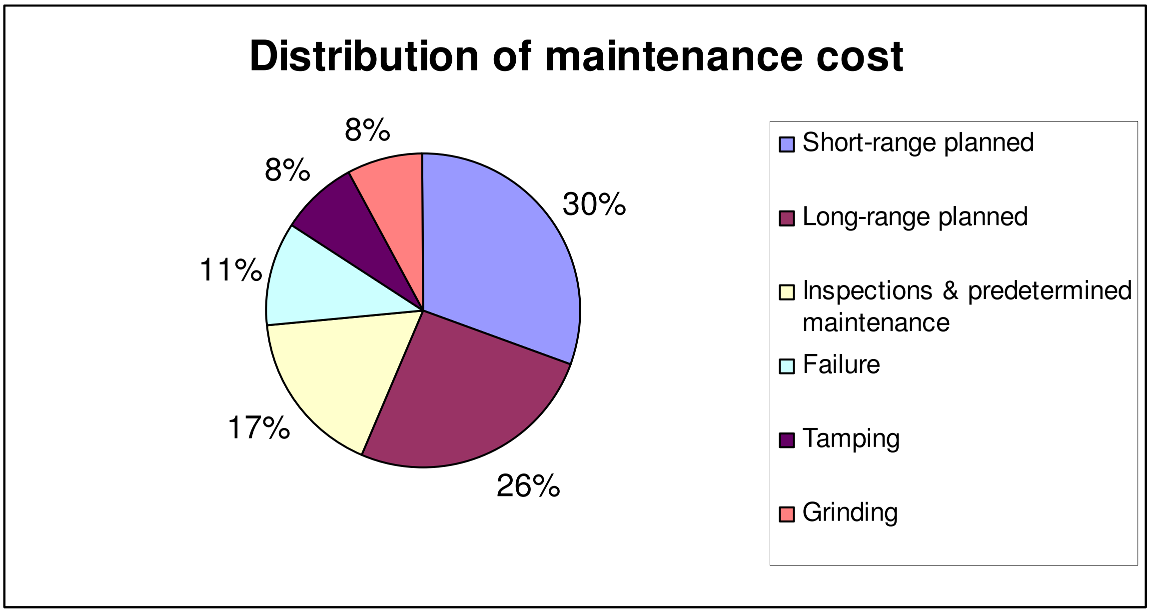

Figure 21 Distributed cost for maintenance of S&C on line 119

Short-range planned actions after inspections are mainly adjustment, build up welding and minimal repairs. This are actions after inspection but are seen by Banverket as immediate corrective maintenance.

Long-range planned actions after inspection include replacement of frogs, switch rails and check rails. This is part of the condition based maintenance.

Failures are mainly problems with not having the switch rail position detector giving a correct signal. Adjustment and replacement of signalling components are common actions. This is corrective maintenance.

For further analysis detailed activities for short- and long-range planned actions and for failure costs are required to break down the costs to the associated maintenance activities and components of a S&C.

6.3 Resulting cost factors of BV

The maintenance costs of the selected BV line 119 with mixed traffic (about 25% passenger and 75% freight traffic) with assumed 18 MGT/year are on the main track about 7.8 times higher than on the side track. The maintenance costs per unit UIC60-300 and UIC60-760 on main track are about the same. The costs for short- and long-range planned actions after inspections and inspections & predetermined maintenance sum up to 73% while the amount for the other activities like failure, grinding and tamping are 27%.

Because the distribution of the maintenance costs to the detailed activities for short- and long-range planned actions after inspections and for failure costs is not yet available, further analysis is required to break down the costs to types of S&Cs and to the associated maintenance activities and components of a switch.

7. Conclusions – Key parameters for track related optimization of S&C

In this chapter the results from chapters 5 and 6 are compiled to identify key parameters for track related optimization of S&C.

7.1 Results DB

The analysis of the selected high speed line with UIC 60 switches, mixed traffic with about 17.5 MGT/year (average) and 458 chosen S&Cs has identified the following key parameters:

a. **50%** of the overall costs are for **inspection, service and test measures.** These are thus the main cost drivers overall at the selected DB line

b. the main cost drivers (**excluding inspection/service/test**) are
   - renewal of switch rails (half set) with about 35%,
   - large elements (not separated between frogs or switch rails etc.) with 17% and
   - frog renewal with about 13%.

c. All together this is an amount of 65% of the costs per S&C while the other activities like welding, maintenance (e.g. minimal repair), tamping etc. sum up “only” to 35% on the selected line.

d. First results from another DB analysis confirm the presented conclusions from the selected high speed line in general but show that the **costs for renewal of switch rails are roughly equal to the costs for renewal of frogs**. A reason for this difference may be caused by speeds of up to 250 km/h on the selected high speed line.

The results of the workshops are separated in technical problems and best practise. Concerning best practise the IM mainly asked for the experiences, approaches or limit values of other railway companies. The DB result (see a.) confirms this issue.

7.2 Results BV

The analysis of the maintenance costs of the selected line 119 with mixed traffic (about 25% passenger and 75% freight traffic) with assumed 18 MGT/year has identified the following key parameters:

a. The main cost drivers (**without inspection/service/test**) are
   - Short-range planned actions after inspections with 30%. This is mainly adjustment, build up welding and minimal repairs. This are actions after inspection but are seen by Banverket as immediate corrective maintenance.
   - Long-range planned actions after inspection with 26%. This includes replacement of frogs, switch rails and check rails. This is part of the condition based maintenance.
   - Costs for inspections & predetermined maintenance with 17%.

   The costs for these measures sum up to 73% while the amount for the other activities inspection, grinding and tamping are of 27%.

b. The maintenance costs per unit UIC60-300 and UIC60-760 on main track are about the same.

c. The maintenance costs on the main track are about 7.8 times higher than on the side track.

Because the distribution of the maintenance costs to the detailed activities for short- and long-range planned actions and for failure costs is not yet available further analysis is required to break down the costs to types of S&Cs and to the associated maintenance activities and components of a S&C. As well as to investigate is the difference between the costs for DB and BV.

7.3 Constraints for data analysis

- Inspection and service activities are based on planned maintenance;
- Insufficient infrastructure data bases for getting data of costs for maintenance with a detailed allocation to several components and maintenance actions;
- This is obviously a problem for all railways. Therefore as the solution adopted in SP 3.1 specific routes have been chosen and analysed
- As far as possible representative lines are selected for the cost factor analysis.
- Operational aspects like use of deviating track, main direction of traffic, placing of S&C (close to bridges and curves) etc. should be part of further investigations because e.g. replacements of switch rails are highly influenced by the number of trains running on the deviation line.

Follow-up analyses for other routes with different characteristics are under way. It will be reported in later deliverables which will also include data analysis from other railways.