NeTIRail

Needs Tailored Interoperable Railway Infrastructure

Deliverable 2.3

Cost/benefit data and application methodology for lean in railway S&C

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Executive Summary

This report provides a collection of items that will be useful for applying analysis of lean and automotive techniques in railway switch and crossing (S&C). The data used in this deliverable were collected from various source, including real data from IMs, datasheets from infrastructure manufactures, scientific publications (journal, conference and workshop articles, research reports, dissertations, etc.). Some comparable data are organized in the form of figures and tables. Other detailed data in the form of spreadsheet or pictures are also attached with this report.

This report also provides the data regarding S&C characteristics, additional fittings for S&C, fastening system and maintenance tasks for S&C, and some new techniques that may improve the performance of S&C and/or optimize maintenance procedures. The data collected include:

- Existing lubricants and lubrication techniques for S&C;
- Layout of S&Cs at stations with their detail parameters;
- Debris-proof systems that can prevent avoid or clear the obstruction of S&C;
- S&C fasteners with great integrity;
- Detail procedures for S&C maintenance;

Climatic conditions along NeTIRail-INFRA case study lines that impact S&C performance.

These data will be mainly used in Task 2.3.2 (Application of lean and automotive industry techniques to railway S&C) of the NeTIRail-INFRA project.

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Abbreviations and acronyms

Abbreviation / Acronym	Description
DLD	Driving and Locking Devices
EC	European Commission
ESSD	Electronic Signaling Safety Device
IM	Infrastructure Manager
LCC	Life Cycle Costing
MTTR	Mean time to repair
RAMS	Reliability, Availability, Maintainability, Safety
R&D	Research & Development
S&C	Switch and Crossing
VSM	Value Stream Mapping
WP	Work Package

1. Introduction

The lean technique, aiming to reduce wastes and optimize the production procedure, has been developed and successfully applied in automotive and other industries. However, few applications in railway industry have been reported. In the NeTIRail-INFRA project, the introduction of lean and automotive techniques into railway S&C will be investigated in the framework of WP 2.

S&Cs are essential components in the railway system. Unlike other parts in the track system, due to some movable components, S&Cs often bring a great proportion of failures in all track failures. Conventional maintenance tasks have to be performed by workers and special machines in the site, when there is no passage of trains. S&C failures and maintenance tasks often result in delay of trains, bring a negative impact on the whole network and cause a great loss to operation. Therefore, the choice of low maintenance S&C components and the optimization of S&C maintenance procedure are important to the railway system.

In order to apply lean and automotive techniques in railway S&C, it is necessary to describe, in detail, their maintenance procedures using value stream mapping (VSM). The current task aims to collect the data regarding S&C characteristics and maintenance procedures according to the requirements of lean analysis. These data include workflow, workforce, work time, machinery used, cost, etc.

All collected data will be finally organized and stored in various forms and then used in Task 2.3.2 (Application of lean and automotive industry techniques to railway S&C) of the NeTIRail-INFRA project.

The rest of the report is organized as follows. Chapter 2 reviews basic concepts pertaining to S&C. In Chapter 3, conventional maintenance actions, including lubrication and installation/replacement are described. The detailed data and relative primary analysis are provided in Chapter 4. Finally, Chapter 5 gives some concluding remarks.

2. Overview of S&C and their components

2.1 Basic concepts

In the railway system, S&Cs are the devices that allow trains to change from one track to another. Switches are not only placed in the infrastructure to connect different lines, but also to connect parallel tracks of the same line (crossovers) in order to give flexibility to track operation. The following sections introduce some concepts that will be used in the current report (European Committee for Standardization, 2003).

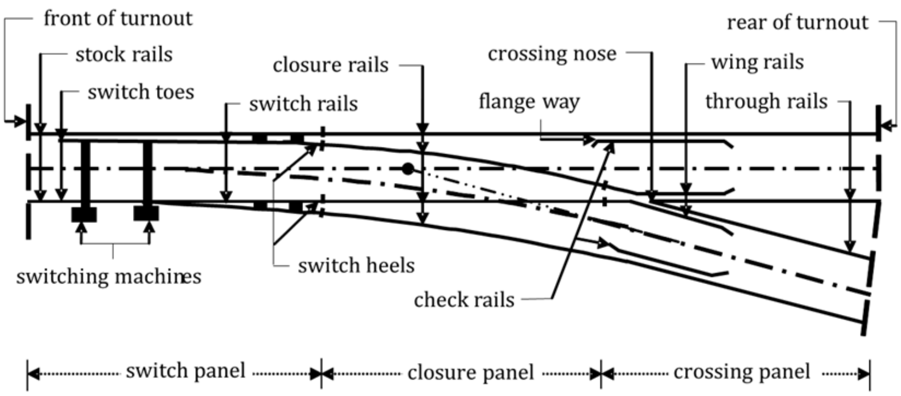


Figure 2.1 - A turnout and its components

2.1.1 Turnout (switch)

A **switch (turnout)** is the layout permitting the passage of rolling stock between two tracks and one common track.

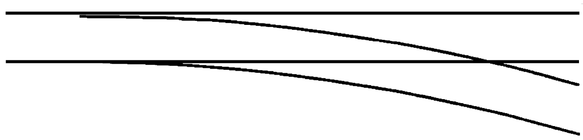


Figure 2.2 – A turnout

2.1.2 Crossing

A **diamond crossing** is the layout permitting the passage of rolling stock on intersecting tracks.

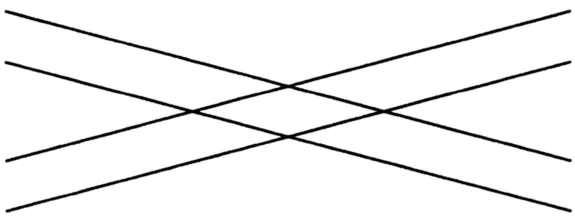


Figure 2.3 - A diamond crossing

2.1.3 Track designation

In the basic design, the straight track is called the **main line**, and the curved track is called the **branch** or **turnout line**.

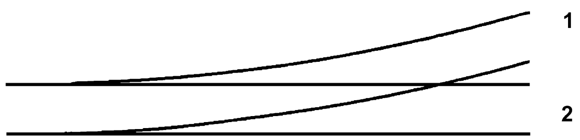


Figure 2.4 - A branch line (1) and a main line (2) in a turnout

2.1.4 Turnout designation

Turnouts are designated by the following symbols:

- RH: diverging to the right
- LH: diverging to the left
- S: symmetrical (or equal split)

When the branch line diverged to the right of the main line, it is a **right-hand turnout**.

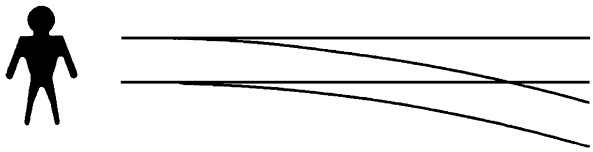


Figure 2.5 - A right-hand turnout

When the branch line diverged to the left of the main line, it is a **left-hand turnout**.

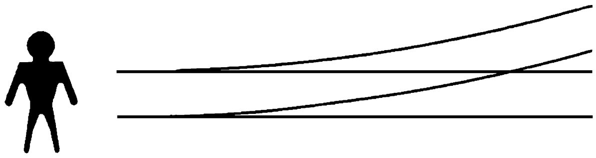


Figure 2.6 - A left-hand turnout

When the two tracks diverge symmetrically from the common track, it is a symmetrical turnout. The machining of each switch rail will be equal, as will the horizontal set (if any) of each stock rail.

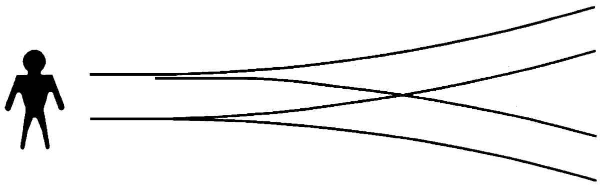


Figure 2.7 - An equal split turnout

2.1.5 Diamond crossing designation

A diamond crossing is either standard or non-standard.

A diamond crossing is standard when both tracks are straight or on curves of the same hand and radius.

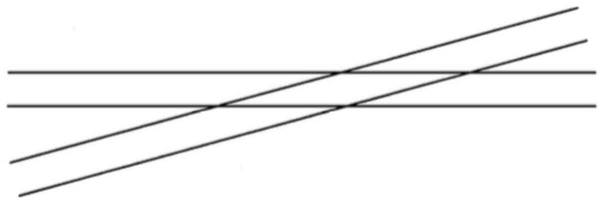


Figure 2.8 - A standard diamond crossing

A diamond crossing is non-standard when one track is curved and the other straight, or when both tracks are curved to different radii or when both tracks are to the same radius but of opposite hand.

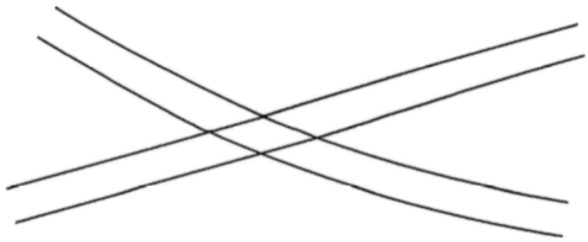


Figure 2.9 - A non-standard diamond crossing

2.1.6 Diamond crossing with slips

A diamond crossing with slips is the layout permitting the passage of rolling stock between two intersecting tracks as well as over such tracks. It may be single or double with variants as follows.

A diamond crossing is with **single slip** when only one connection is made between the intersecting tracks. These are designated SS (single slip; or diamond crossing with single slip).

Figure 2.10 - A diamond crossing with inside single slip

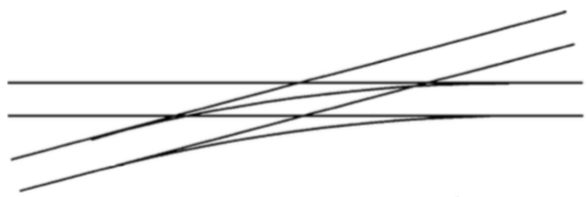


Figure 2.11 - A diamond crossing with outside single slip

A diamond crossing is with **double slip** when both intersecting tracks are connected. These are designated DS (double slip; or diamond crossing with double slip).

Figure 2.12 - A diamond crossing with inside double slip

Figure 2.13 - A diamond crossing with outside double slip

2.2 Layout of S&C

A **layout** is any combination of switches and crossings.

2.2.1 Crossover

A **single crossover** are two turnouts placed heel to heel combining to join two adjacent tracks.

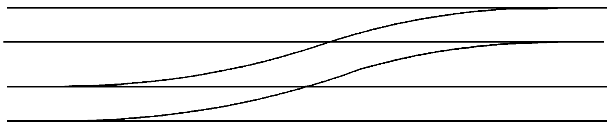


Figure 2.14 - A single crossover

A **scissors crossover** is a layout comprising two intersecting crossovers.

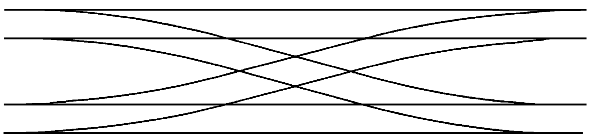


Figure 2.15 - A scissors crossover

A **half-scissors crossover** is a part layout, as above comprising two turnouts of opposite hand in the same track and the central diamond crossing.

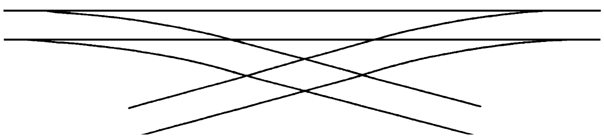


Figure 2.16 - A half-scissors crossover

2.2.2 Junction

A **single junction** is a layout composed of a turnout and a diamond crossing with or without slips, allowing the intersection of adjacent tracks by a track also partially or completely connecting them.

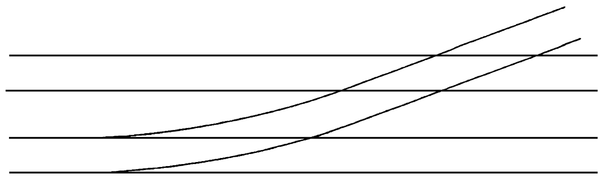


Figure 2.17 - A single junction

A **double junction** is a layout comprising two turnouts and a diamond crossing (with or without slips) combined to give a double track divergence from the double track main line.

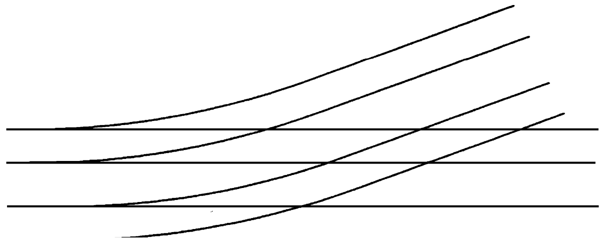


Figure 2.18 - A double junction

A crossover, single or double junction, is said to be **right** or **left hand** according to the direction of divergence from the major route.

In railway stations, the operational impact caused by an incident on the track is directly related to the number of crossovers or junctions in the line, which evinces their importance for IMs.

2.2.3 Optimised layout of S&Cs at stations

Task 2.3.2 of NeTIRail-INFRA will include optimising the layout of S&Cs at stations. To accomplish this task The University of Sheffield will model the station layouts using a model, which has been developed using the Maple mathematical and analytical software.

Current station layouts and traffic data have been gathered from the infrastructure manager partners in NeTIRail-INFRA and from modelling different layouts it will be possible to optimise the system either by removing unnecessary S&C, reconfiguring or even adding further S&C.

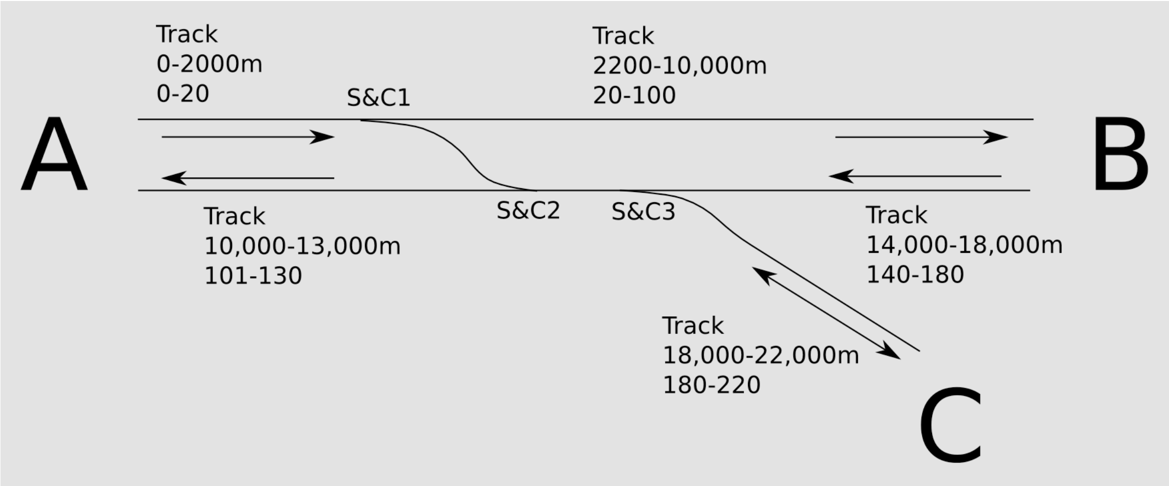


Figure 19 - Example of a simplified S&C layout being modeled

The model will use reliability data (e.g. failure rate based on mean gross tonnes or traffic or switch movements, mean time to repair etc.) for each S&C as input, as well as traffic and loading data, and timetables. The passage of individual trains will be modelled according to the timetable; this traffic data then feeds into the reliability of the switch. The failures and the impact on the traffic flow can therefore be predicted.

The optimum solution will be different for the different railway types within the project; in some cases, flexibility and reliability may be sacrificed for reduced operating costs especially for underutilised railways (Figure 2 & 3 shows an example of reducing the number of S&C helped with operating costs and improved the performance at York station in UK). Or in the case of capacity constrained routes increased reliability, flexibility and recovery time from incidents will take priority over maintenance and installation costs and in this case extra system redundancy may be justified. The results will therefore be a customised solution selected case study stations based on the requirements for that particular line.

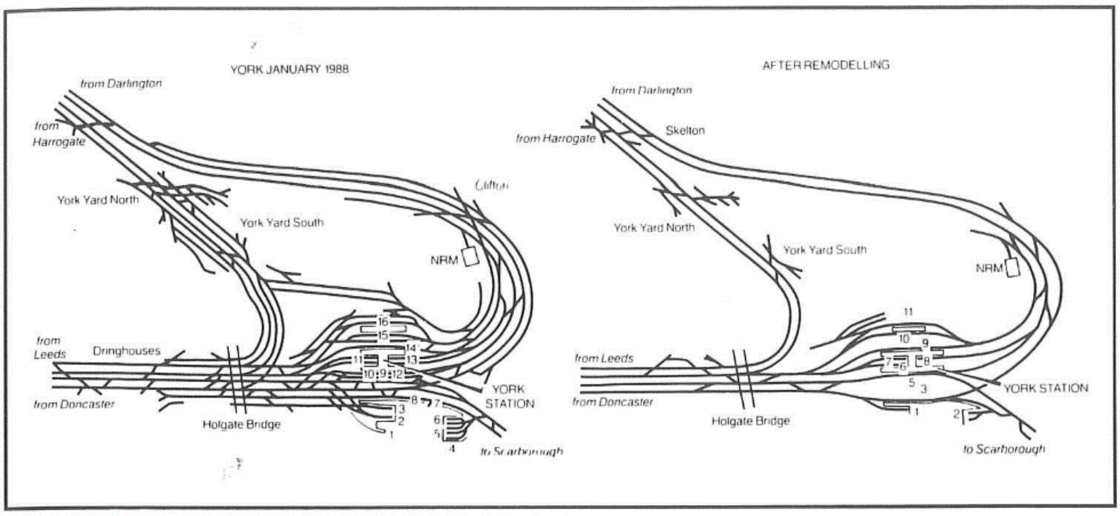
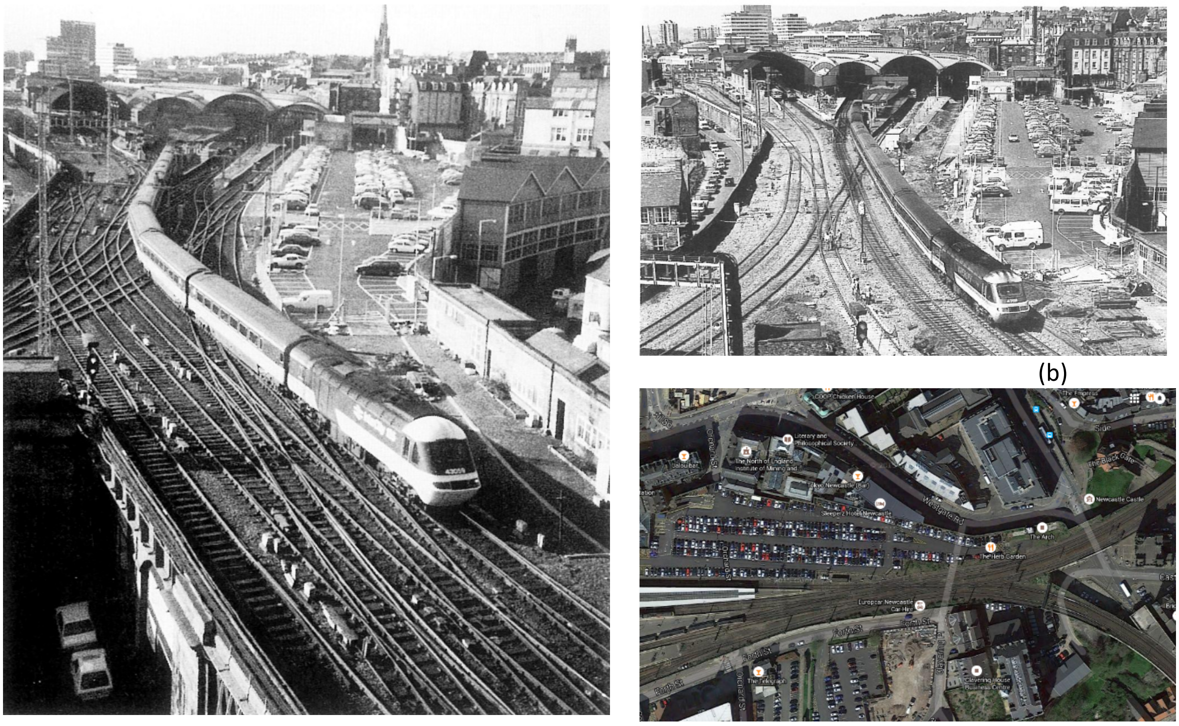


Figure 20 - Diagrams showing the old and new layouts of running lines in the York area (BR)



(a) (b) (c)

Figure 21 (a) a picture of old layout, York station (b) Picture of new layout (c) Google Earth picture of the new layout

2.3 Components of S&C

A turnout consists of three turnout panels: switch, closure and crossing panels.

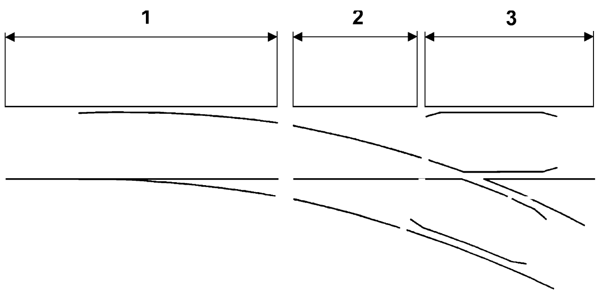


Figure 2.22 - Switch panel (1), closure panel (2) and crossing panel (3)

2.3.1 Switch panel

The **Switch panel** is the part of a turnout or layout ensuring the continuity of any one of two or three diverging tracks at the beginning of the divergence, consisting of two half sets of switches assembled together, usually with bearers. As shown in the figure below, the switch panel of a right-hand turnout has the following components:

1. Left hand half-set of switches
2. Right hand half-set of switches
3. Left hand curved switch rail
4. Right hand straight switch rail
5. Left hand straight stock rail

6. Right hand curved stock rail
7. Heel baseplate
8. Block or Heel block
9. Fishplate block (not shown)
10. Stud/distance block
11. Slide baseplate (or Slide plate)
12. Stretcher bar bracket
13. Stretcher bar
14. Anti-creep device (not shown)
15. Switch Toe/Tip
16. Switch Heel
17. Switch Rail Joint
18. Stock Rail Joint
19. Stock Front Joint
20. Soleplate
21. Sleepers (Bearers, not shown)

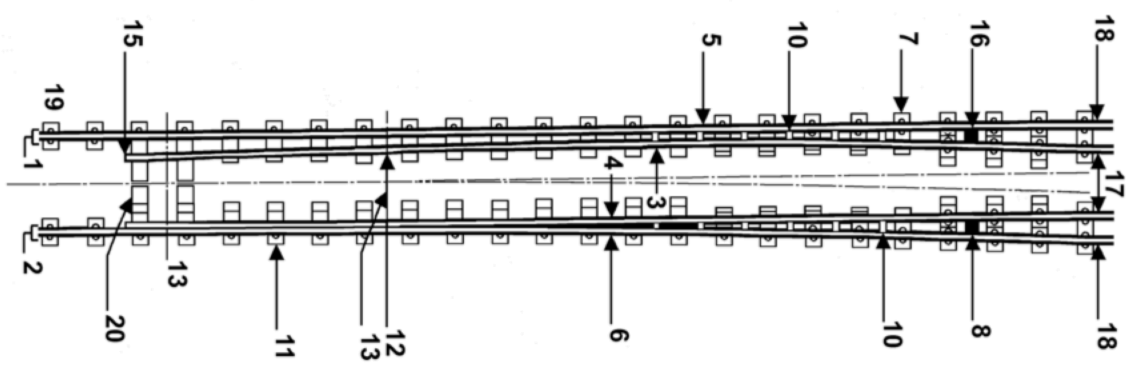


Figure 2.23 - A switch panel

A **switch rail** (or **switch blade**) is a movable machined rail, often of special section, but fixed and/or joined at the heel end to a rail to provide continuity of wheel support. The two switch rails in a set are the two inside rails. A switch rail is described as right or left hand according to whether it is part of a right hand or left hand half-set of switches.

A **stock rail** is a fixed machined rail, ensuring the continuity on the main or diverging track with the switch in the open position. The machined part of the stock rail supports its switch rail in the closed position, giving continuity of line through this switch rail. The two stock rails in a set of switches are the two outside rails. A stock rail is described as right- or left-hand according to whether it is part of a right-hand or left-hand half-set of switches.

Besides the permanent way components above, the following components may also belong to the panel:

Point machine (actuator) is a mechanical system, which induces the switching movement between the two extreme positions. The common types of point machines are given in (INNOTRACK, 2008).

Locking device can lock the switch in one position to prevent movement of the switch rails as traffic passes.

Position detection devices detect the position of the switch. They are linked to the signalling system.

Driving devices are mechanical components, which assist the movement of the switch rails, including drive rods, slide chairs and rollers.

Heater is used in cold areas to prevent the switch from freezing.

Slide plates allow for free sliding and the addition of lubrication to ease switch change movement, and prevent the switchblades from being pressed into timber sleepers under load.

2.3.2 Crossing panel

A **crossing panel** is a part of a turnout or layout ensuring the continuity of two intersecting routes by means of an intersection of opposite running edges and consisting of a common crossing, 2 outside rails, and 2 check rails complete with small fittings and assembled together, usually with bearers.

The components of the common crossing panel as well as examples of alternative checkrail supports are as follows:

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

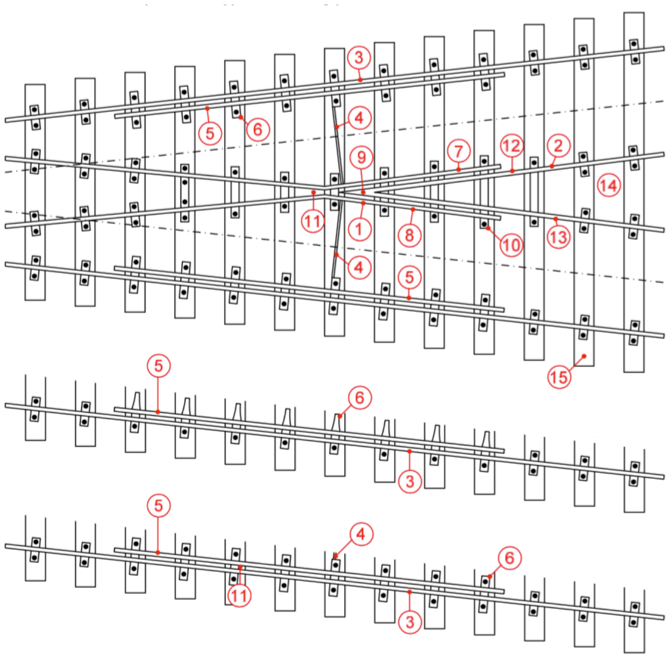


Figure 2.24 - A crossing panel

A **vee** is the parts of the crossing forming the shape of a letter "V" which forms support to the wheels.

A **nose** is the point at which the vee commences, at the level of the gauge reference plane.

A **point rail** is the rail in a built-up crossing which when machined forms the crossing nose.

A **splice rail** is the rail in a built-up crossing, which is spliced into the point rail, forming the crossing vee. The crossing is described as "left hand splice" or "right hand splice" depending on the splice position when the observer is facing the nose.

Wings or **wing rails** are the outer parts of the common crossing, which support and guide the wheels across the flange way gap.

Outside rails are the running rails opposite the crossing at a distance of gauge away.

A **check** or **checkrail** is the special section bar ensuring (by guidance of the wheel) the safe passage of the axle opposite the neck gap of the common crossing.

A **checkrail strut** is the part joining the common crossing to the checkrail ensuring the maintenance of the correct position of the checkrail relative to the crossing nose.

A **checkrail support** is the part supporting the checkrail.

A **heel of crossing** is the physical end of the common crossing vee at its open end.

2.3.3 Closure panel

A **closure panel** is a part of a layout or turnout located between the switch panel and the crossing panel consisting of rails with fastening system and usually on bearers.

Fasteners (or **fastening systems**) are a means of fixing rails to sleepers, in order to keep rails in proper position. No matter the environment, fastening systems need to be resilient, easy to install and customizable to a variety of specifications.

A well-designed fastening system not only preserves proper track geometry, but will also help to extend the life of other components.

The following table is a non-enumerative list of manufacturers of fastening systems in the world, among which there are some designing and producing special fastening systems suitable for S&C, e.g., Vossloh, Pandrol, Schwihag.

Table 2.1 - Some manufacturers of fastening systems in the world

Manufacturer of fastening systems	Headquartered in (Country)
AGICO Group	China
Alex Railway Fastening	China
Alom	Netherland
Amsted Rail	US
AVeng	South Africa
A&K	US
Delkor	Australia
Fasten it	Italy
Jinstar Railway Materials	China
KRT	Ukrain
KVT-Fastening AG	Switzerland
Lederer	Germany
L.B.Foster	US
Molytex	Denmark
Patil	India
Prestigetrack	India
Schwihag	Germany
Severstal	Russia
Southco	US
Swagefast	South Africa
United industrial	Australia
VoestAlpine	Austria
Vossloh	Germany
Wirthwein AG	Germany

3. Maintenance tasks of S&C

3.1 Overview of maintenance tasks of S&C

Compared with plain track (i.e. straight tracks or curves, only made up of ballast, sleepers and rails, rigidly connected to each other), an S&C contains several special features:

1. It has moving parts, the switchblades, which make it more like a machine than like a static component.
2. It is subjected to high, concentrated, dynamic forces, mainly due to the flange way opening at the frog which a train wheel has to “jump” and the fact that the curved direction has a small radius without cant, which causes high lateral forces.
3. A failure of one of the parts can lead to direct derailment. Where, on plain track, a broken rail can still be passed by a train wheel due to built-in redundancy, a broken switch blade will potentially lead to direct derailment of the first train that will run over it.

These properties lead to special maintenance and renewal requirements.

There are various maintenance actions for an S&C. On a short-term basis the lubrication of slide chairs can be done regularly. In the longer term, surface welding, tamping and grinding are needed, and are generally done after a period of 1 – 5 years. A very long maintenance interval is required for the replacing of switchblades, crossing and renovating of point machines. These are done on a time scale of 5 – 20 years. Most of the maintenance decisions are taken based on an inspection report. A regular inspection interval might be 1 – 3 months. In some countries a simplified visual inspection is done every week on the most important S&Cs (Nissen, 2009). The planning and organisation of the maintenance is affected by factors such as availability of track, traffic, geographical location and climatic conditions.

Maintenance is divided into preventive and corrective maintenance. The actions for **preventive maintenance** is based on measured and visual inspection and the **corrective maintenance** is based on failures reported that could affect the traffic directly. Therefore, some corrective maintenance will induce train delays as well (DB, 2009).

Preventive maintenance for S&Cs can be divided into more general actions such as

- Grinding
- Tamping

More specific actions for the S&Cs includes

- Welding
- Small maintenance activities (no more than 15 minutes)
- Renewal of subsystem
- Repair
- Others

Corrective maintenance includes

- Small maintenance activities (no more than 15 minutes)
- Repair
- Others

Each maintenance action is described by the following parameters:

- Frequency (number of actions per year)
- Repair time (MTTR)
- Cost for machines/equipment
- Cost for spare parts

Some more general parameters are

- Logistic delay time
- Probability that a corrective maintenance will lead to train delay
- Train delay time per stopping failure

Using three parameters for cost and give the train delay time for corrective maintenance can incorporate train delay. No train delay is calculated for preventive maintenance actions.

3.2 Inspection and diagnostics of S&C

Maintenance for S&Cs is normally based on inspection reports. The inspections can be divided into four types (Nissen, 2009):

- Simple visual inspections
- Detailed visual inspection
- Measured inspections
- Non destructive testing

Simple visual inspection can be performed with 1 – 4 weeks interval, just to have an overview and confirm that there are no safety problems.

Detailed visual inspection and **measured inspection** are normally performed at the same time and can be performed with an interval of 2 – 6 months. Safety issues are noted. Then, the inspector proposes the issues of replacement or repair in the longer term.

Non-destructive testing is done using ultrasonic equipment to check for internal cracks in the rails and crossing materials. The track recording car measuring level, alignment, twist and gauge can also be treated as a non-destructive testing although it is normally referred to condition monitoring.

Actions that are taken as a consequence of the inspection reports or a following failure occurrence are:

- Adjustments
- Lubrication
- Cleaning/Rinsing
- Functional control
- Repair
- Replacement

- Grinding
- Tamping
- Compressing the ballast under certain “dancing sleepers”
- Restoration (replacement of all worn parts at the same time)

3.3 Lubrication of S&C

The lubrication of S&C is very important. An S&C failure due to insufficient lubrication may cause traffic disruptions, possibly affecting the whole rail network.

During operation, insufficient lubrication can cause dry chairs failure. The friction between switch rail and the slide chair makes it difficult to change the direction of switch, which may result in serious switch failure. This means slide chairs need immediate lubrication.

Figure 3.1 - Dry slide baseplate (Hassankiadeh, 2011)

In the current task, various lubricants and lubricating technique will be discussed, and the relative effectiveness will be analyzed.

The conventional lubrication is performed manually on a regular basis. The main steps of such a task is as follows:

1. Spraying under the switch rail at the slide plates.
2. Spray liberally under the switch rail along the slide plates and allow penetrating.
3. Once the switch has been reversed apply along the slide plates at the other side of the switch rail and allow penetrating.
4. Wipe both sides of the plate with a cloth.

The application of lubricant can be also performed using a brush.

During this period, the lubricant creeps over the slide chair to displace water and penetrate under the switch rail, into the switch heel and other inaccessible areas to cleanse and break down corrosion, old grease and other deposits. Generally, standard lubricant needs to be reapplied periodically. (MAINLINE, 2014)

The requirements for lubricant in switches are as follows:

1. Basic characteristics, such as low friction coefficient, high corrosion and wear protection and good adhesion to the slide plate.

2. A lubricant must always show excellent water and UV resistance and maintain a stable lubricating film, whenever it is used under harsh environmental conditions such as heat, snow, ice, rain or dust.
3. The choice of lubricant should be cost-effective. A lubricant with a long service life ensures long maintenance intervals and low consumption.
4. A lubricant should be tailored to its intended place of use. The choice of lubricant can be varied from different countries, or even different regions in a country, in order to satisfy the different climatic and traffic requirements.
5. A lubricant should be environment-friendly. For outdoor applications around switches, the lubricant is preferred to be biodegradable. This helps avoid some environmental issues or legal regulations.
6. Easy application with conventional manual spraying or brushing, or new automatic lubricators.

The frequency of lubrication and the performance of lubricants are influenced by various conditions.

1. Temperature: The lubrication of S&C must be intensified in the wintertime, since the heating has the effect that more lubricant is necessary (transrail, 2006).
2. Water: Water in the lubricant damages the lubricant and thus the lubrication interval is much shorter time than originally expected.

Lubrication of S&C is often performed with the application of some special lubricant. Whether lubricating oil or grease is applied, the objective is the same, i.e., building an oil film between switchblade and slide plate in order to reduce the friction relative to each other. Achieving this goal reduces friction and can help prevent wear caused by direct surface-to-surface contacts.

Characteristic parameters, such as service temperature range, viscosity, biodegradability, application method, are very important in the choice of lubricants.

The following table provides a comparative synthesis of various lubricants.

Table 3.1 - Comparison of characteristics of lubricants

Lubricant	Manufacturer	Service Temperature (°C)		Viscosity at 40°C (mm^2/s)	Biodegradability (Standard)	Application method	Approval, recommendations, or used by
		Min.	Max.				
BECHEM Ecorail EES 46 (BECHEM)	BECHEM	-30	90	46	OECD 301 C		
BECHEM Ecorail 2001 PLUS (BECHEM)	BECHEM	-30	80	11	OECD 301 C	Spray	SNCF
BECHEM Ecorail 2002 (BECHEM)	BECHEM	-30	80	17	OECD 301 C		
BECHEM Ecorail 2009 (BECHEM)	BECHEM	-30	80	46	OECD 301 B		
BECHEM Ecorail 2012 (BECHEM)	BECHEM	-30	80	20	OECD 301 B		DB, SNCF
BECHEM Ecorail 2016 (BECHEM)	BECHEM	-30	80	20	OECD 301 B		
CT-SPS-600 (Chemtools)	Chemtools	-10	50			Spray	
BIO.NATURAIL (CONDAT)	Condat Lubrifiants	> -25		22	CEC-L-33-A-93	Spray[1]	SNCF
Condat Bio (Condat)	Condat Lubrifiants	-20	50	46	CEC-L-33-A-93		
TRAMLUB 384 G PLU (Fuchs LubriTech)	Fuchs Lubritech	-35	100				
TRAMLUB S 3 (Fuchs LubriTech)	Fuchs Lubritech	-25	100	165			Bijur Delimon, Rebs
TRAMLUB S 5 (Fuchs LubriTech)	Fuchs Lubritech	-30	100	69			Bijur Delimon, Rebs, Secheron.
TRAMLUB SPL-F 1 (Fuchs LubriTech)	Fuchs Lubritech	-35	100	30			
TRAMLUB F 234 G (Fuchs LubriTech)	Fuchs Lubritech	-30	100				DB
Loctite LM416 (Henkel)	Henkel						Network Rail, SNCF
SwitchLub 60/00 (IgraLub)	IgraLub	-30	120	25-28.5	OECD 301 B	Spray	CPTM,
SwitchLub 60/09 (IgraLub)	IgraLub	-30	120	30-40	OECD 301 B		

[1] Spray with a portable SNCF-approved spray gun.

Table 3.2 - Comparison of characteristics of lubricants (continued)

Lubricant	Manufacturer	Service Temperature (°C)		Viscosity at 40°C (mm^2/s)	Biodegradability (Standard)	Application method	Approval, recommendations, or used by
		Min.	Max.				
Interflon Lube EP (Interflon)	Interflon	-43	170		OECD 301-F	Spray/brush	
Kluberrail AL 32-2000 (Klüber)	Klüber	-20				Spray	
Kluberrail AL 32-3000 (Klüber)	Klüber	-10				Spray/brush	
Kluberrail ALO 32-4000 (Klüber)	Klüber					Brush	
SINTONO TERRA HLK (Lubcon)	LUBCON	-25				Spray	
SINTONO TERRA W (Lubcon)	LUBCON	-40	120				
TURMOFLUID BIO E (Lubcon)	LUBCON						
TERRAGLISS WZ (Lubcon)	LUBCON	-40	130				
TERRASOL 100 WT (Lubcon)	LUBCON						
Lubriplate Low Temp (Lubriplate)	Lubriplate	-51	121				
PRECISION XL RAIL CURVE GREASE (Petro-Canada)	Petro-Canada	-33	185				
UltraLube 10972/10973/10977/10978 (UltraLube)	Plews & Edelmann					Spray/brush	
rhenus LSN 04 (rhenus)	rhenus Lub	-40	120				DB, ÖBB,
Rhenus LWN 04 (rhenus)	rhenus Lub	-40	120				SNCF, Finland
Glidex (SolliQ)	SolliQ	-35					
Ice Free Zone (SolliQ)	SolliQ	-40				Brush/spray /pour	

3.4 Replacement

The most complicated and costly replacement that can be carried out is the replacement of a complete switch or crossing at once. However, when multiple components at the same time, or when irreplaceable components reach the end of their technical lives, this replacement of a complete switch becomes necessary (Zwanenburg, 2007).

3.4.1 Classification of S&C replacement methods

Three main methods for S&C renewal can be identified:

- Assembled on site;
- Pre-assembled in the vicinity of the worksite;
- Modular switch (just in time).

According to DB, the proportion of these three methods is 9% assembled on site, 90% pre-assembled at the track side and less than 1% for modular switch (before 2014). Only in some Eastern European countries the proportion of switches assembled in site is higher.

It is shown that assembly of the S&C adjacent to the worksite is the most common practice across Europe due to the following advantages:

- On acceptance of the S&C at the factory, disassembly, transport and reassembly near the renewal site are relatively straightforward.
- S&C can be constructed near the worksite and installed with minimised disturbance to traffic.
- The quality of the components and installed geometry is known to be good upon commissioning.

However, the use of modular switch concept is expected to grow in some countries given that this method allows a reduction of not only the installation time but can also facilitate the pre-renewal significantly works (no need to negotiate with landowners if there is no available space for the assembly of the new switch) and post-renewal works (less time required for commissioning). This method could be very important from the lean aspect.

3.4.2 Phases of S&C replacement methods

As it was mentioned before, there can be found a wide range of methods for replacing an S&C. Nevertheless, all replacement methods follow a similar structure, which can be organized in four main phases.

1. Pre-renewal works
    - Preparation of storage areas
    - Transport of replacement components to site
    - Pre-assembly of the new switch in the storage area (in case it is required)
    - Topography works previous to installation
2. Removal of the old S&C and site preparation
    - Dismantling and removal of the old S&C
    - Removal of the upper part or the whole layer of ballast

3. Installation of new S&C
    - Adding of new ballast (and optionally placing of geogrid)
    - Laying and assembly of the new switch panels
    - Welding or clamping
    - Initial track geometry restoration
    - Control system commissioning
    - Final commissioning and testing
    - Dynamic Track Stabiliser (optionally)
4. Post-renewal activities
    - Welding and stress release (if it is not done during the installation phase)
    - Final track geometry restoration
    - Final inspection and acceptance

Several practices from different European countries (Germany, Spain, Sweden, Czech, Hungry, Turkey and UK) have been summarized in the Deliverable 3.3 of MAINLINE project (MAINLINE, 2014).

3.5 Techniques and equipment to reduce maintenance work

3.5.1 Debris-proof fittings for S&Cs

Obstructed turnout occurs due to ice or when ballast particles are thrown out. The obstruction is generally caused during cold weather or for high-speed train movement. In order to avoid or clear such obstruction, various systems can be applied.

3.5.1.1 SwedeSafe (SwedeSafe)

SwedeSafe, a Swedish company specialised with solutions to keep surfaces free of snow and ice applies its technology to the rail industry. The system is 50% more energy efficient than the high temperature hot water piping or heating cable (Enno Wiebe, 2010) used to melt ice/snow. The technology used is simple yet efficient. The plates are supplied by 48V electricity. They are connected in parallel in groups of 2—5 units. The temperature of each unit is controlled individually by a sensor/transmitter connected to a control unit. The controller unit guaranties that proper power is delivered to each plate. The energy consumption per unit is of the scale of 150—180 W per square metre.

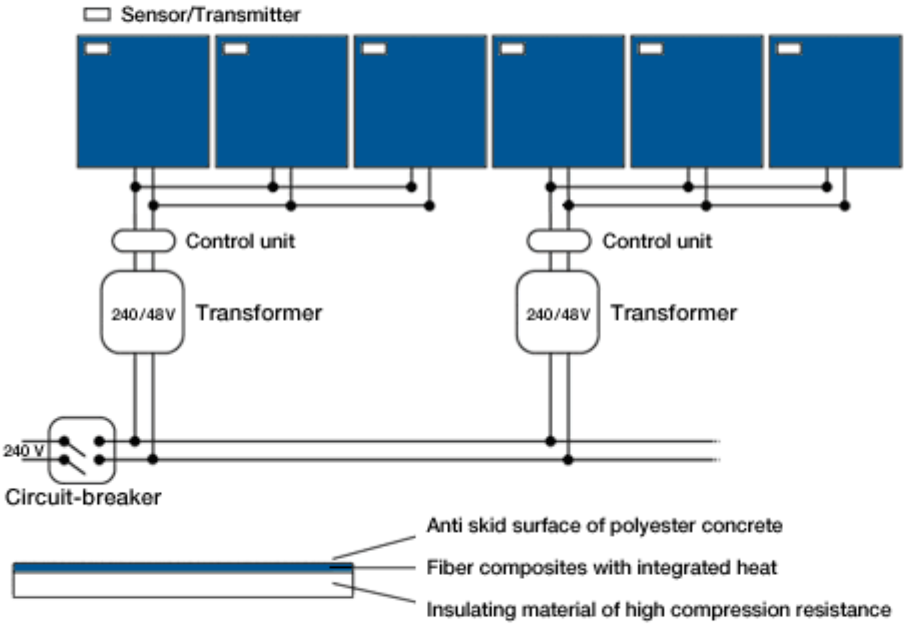


Figure 3.2 - Technology behind SwedeSafe (SwedeSafe)

Figure 3.3 - SwedeSafe on a railway (Enno Wiebe, 2010)

3.5.1.2 Heating space between rails

Another simple way to prevent switches from freezing is to heat the space between the rails and not the rail itself. The length of the wire can be shorter than the rail itself as the warmth is transferred by conduction to a longer part of the rail. (Bettez, 2011)

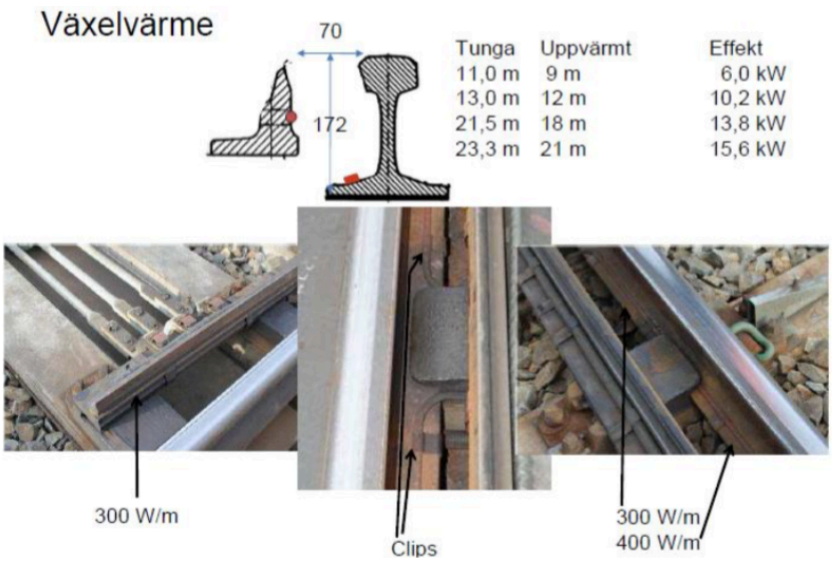


Figure 3.4 - Positioning of heating wire

3.5.1.3 Inductive switch heating (Werf, 2016)

One alternative concept for switch heating is the inductive switch heating (Werf, 2016), which is a principle similar to the use of inductive heat for a stove for cooking.

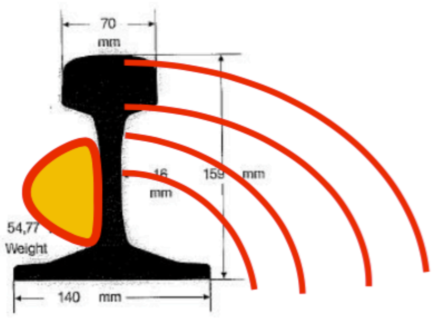


Figure 3.5 - Rail with inductive heating (Werf, 2016)

The main advantage is that the rail is heated with less loss of heat compared to actual systems. Another advantage is that the required equipment is less vulnerable. The system is maintenance free and robust. In the Netherlands a research work is going on to investigate if this will reduce melting time of snow and/or ice.

3.5.1.4 SnowProtec solution (Vossloh, 2014)

SnowProtec, the product developed by Osborn has been available since 2003 and has been installed at more than 1000 turnouts. SnowProtec has the main function in its task to protect turnouts from drifting snow (or other wind born disturbing materials), with the function to secure high availability and functionality of the turnout. The system works together with electrical- or gas- heated heaters for switches (Vossloh, 2014).

Snow protection in the form of wind shield for tongue and movable crossing helps to maintain heat from the switch heating and minimize drifting snow coming into the switch. This solution minimizes or completely avoids manual clearing from snow and ice. Snow protection and heating are completing each other in the task to maintain functionality of switches even in difficult weather conditions.

Figure 3.6 - A track equipped with SnowProtec (Vossloh, 2014)

3.5.1.5 Switch roof (Werf, 2016)

The idea of a winter-proof switch with a switch roof is to prevent blocks of snow and ice from falling in the open space of tongue and stock rail (Werf, 2016). The mechanism of the roof is directly connected to the switch mechanism so there is no additional power engine needed.

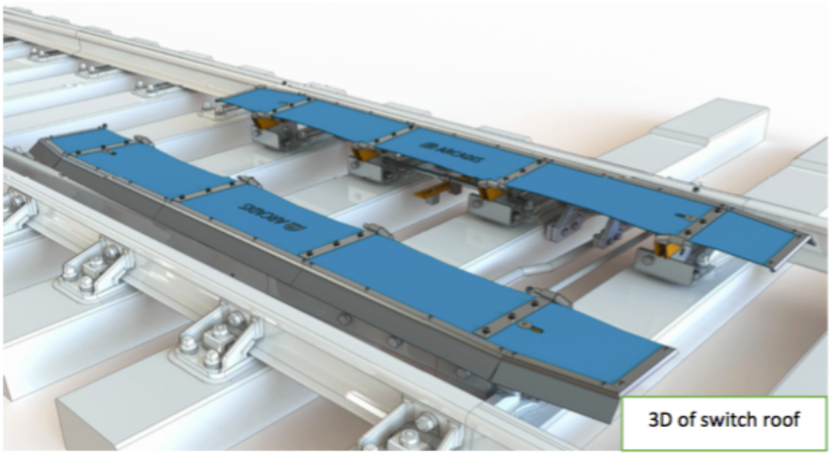


Figure 3.7 - 3D of final design with optimized roof (Werf, 2016)

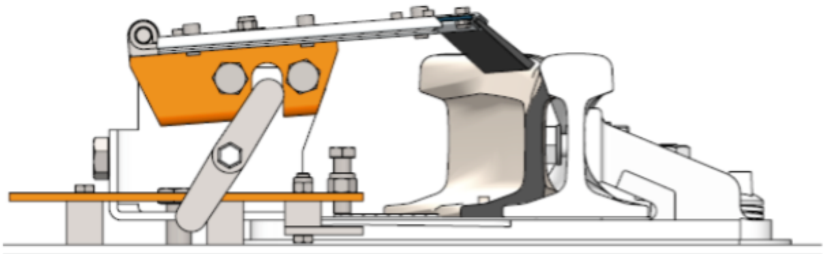


Figure 3.8 - Cross-section of optimized switch roof with brush (Werf, 2016)

The innovative idea can be applied solitary or in combination with existing heating systems.

The switch roof aims to improve the reliability of travelling by train in wintertime and is a possible economic alternative by saving energy.

3.5.1.6 Air/water injection

Air or water injection is applied in, for instance, to remove blocking ice and snow in important switches by either melting it or blowing it away. However, melting snow to water gives a problem with freezing water in other locations and is probably not a good solution in areas with constant low temperatures.

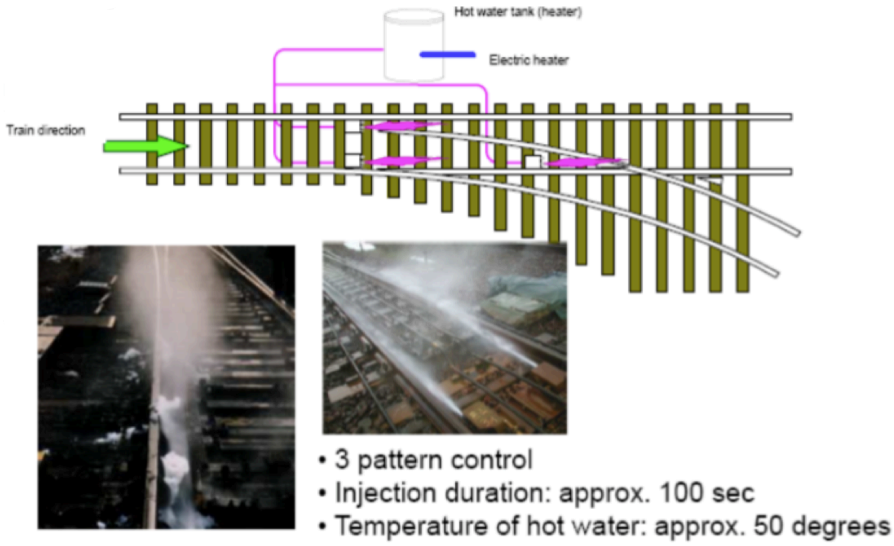


Figure 3.9 - Hot water jet injection melting device at East Japan Railway Company (Kloow, 2011)

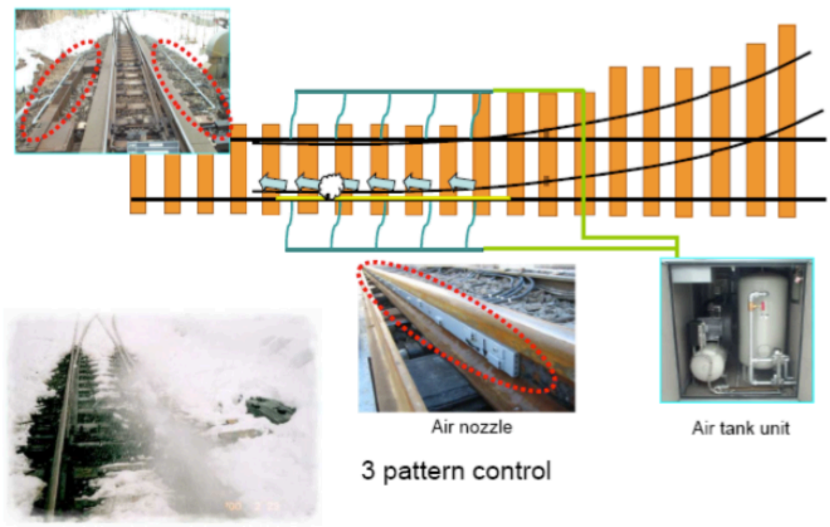


Figure 3.10 - Air injection snow removal device at East Japan Railway Company (Kloow, 2011)

3.5.2 Fasteners of S&C

Conventional fastening systems often consist of a large number of components, which makes the installation work complicated and brings possibilities of component failures. In order to overcome these problems, fasteners with great integrity will be proposed by the current project. Such systems can simplify the installation and maintenance work of fasteners for S&Cs. This section will provide data about fasteners that fit S&C with integrity.

The following table gives some comparative aspects regarding various fastening systems of S&C.

Table 3.3 - Some fastening systems of S&C

Model	300W	W 21 T	W 30 T	e-Clip 1800/2000	Re	ADH
Manufacture	Vossloh	Vossloh	Vossloh	Pandrol	Pandrol	Pandrol
High speed rail	●	●		●	●	
Conventional rail	●	●	●	●	●	●
Urban rail				●	●	●
Heavy haul rail			●	●	●	
Slab track	●					●
Ballasted track		●	●	●		●
Concrete sleeper		●		●	●	●
Steel sleeper				●	●	
Timber sleeper				●		
Applied in (Country)	China, France, Germany, UK		Russia (for test)	Indonesia, Japan, Singapore, UK	Belgium, UK	

3.5.2.1 ADH System (PANDROL)

The Bonded direct fixation fastening (DFF) has been developed to directly combat corrugation and vibration problems caused by major dynamic forces generated from passing trains. The Bonded DFF ADH fastening system has 2 variants. A standard model is valid for both running track, and customised models for switching zones. Its deployment reduces vibrations from passing trains and militates against the development of some types of corrugation.

As shown in the figure below, the ADH system consists of the following components:

1. Vulcanized DFF baseplate;
2. Elastic fasteners (Pandrol e-Clip shown);
3. High resistance anchoring systems;
4. Adjustable washers for lateral adjustment;
5. Rail pad (under rail - not shown) depending on corrugation;
6. Adjustment shims (under rail - not shown).

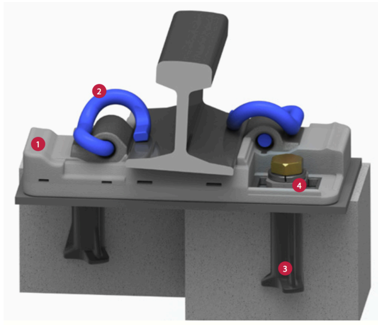


Figure 3.11 – PANDROL's System ADH

The ADH system has the following features:

- Vertical and lateral stiffness
- Vibration attenuation
- Electrical insulation
- Transfer of lateral forces
- Construction

The DFF ADH system can be provided in various lengths to suit turnout applications and is also suitable for steel bridges and ballasted tracks.

3.5.2.2 System e-Clip 1800/2000 (PANDROL)

System e-clip 1800/2000 is developed by PANDROL. It is suitable for the application of concrete, steel and timber (on baseplates) sleepers and S&C. It contains few components and has been applied in Japan, Singapore, Indonesia and UK.

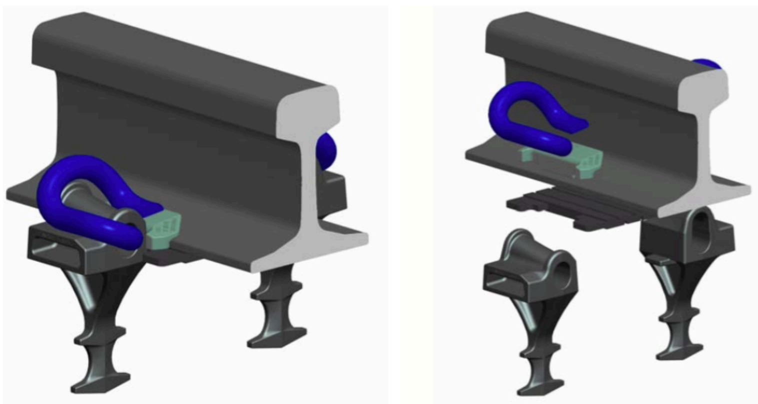


Figure 3.12 – PANDROL's System e-Clip 1800/2000

3.5.2.3 Re system (PANDROL)

Re system is a rail fastening system developed by PANDROL. Compared with conventional e-clip system, it has fewer components and can be installed more easily. It adopts the two-part insulator concept developed by PANDROL for the FASTCLIP system.

The system consists of the following components:

1. PANDROL Re clip with integral toe insulator;
2. Rail pad with integral side post insulators;
3. Cast SGI shoulder (New or existing component).

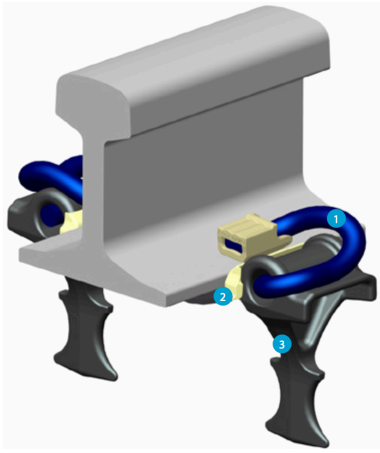


Figure 3.13 - PANDROL's Re system

Re SYSTEM rail pads are supplied with side- post insulators already attached. This reduces time and effort when laying out and installing components on site. Re SYSTEM is also supplied with toe insulators already in place on the toe of the clip. This further reduces installation time and the number of loosing components on site.

This system has been installed on Network Rail at Bawtry (200 km/h speed and 25 T axle loads) and in Belgium.

3.5.2.4 System W 21 T (Vossloh)

System W 21 T, a rail fastening system developed by Vossloh, is on the basis of the W 21 fastening system (Vossloh). It can be adapted to the most different requirements in the field of ballasted track construction; for instance, by inclined plates, that allow rail inclination of 1:20 or 1:40. With this, expensive fastening systems with (ribbed) base plates may be replaced. As shown in the figure below, the system consists of the following components:

1. 2 W-shapes of the Skl 21;
2. 2 angled guide plates;
3. 1 elastic rail pad made of cellentic;
4. 1 inclined plate;
5. 1 securely clamped with screw-dowel-combination.

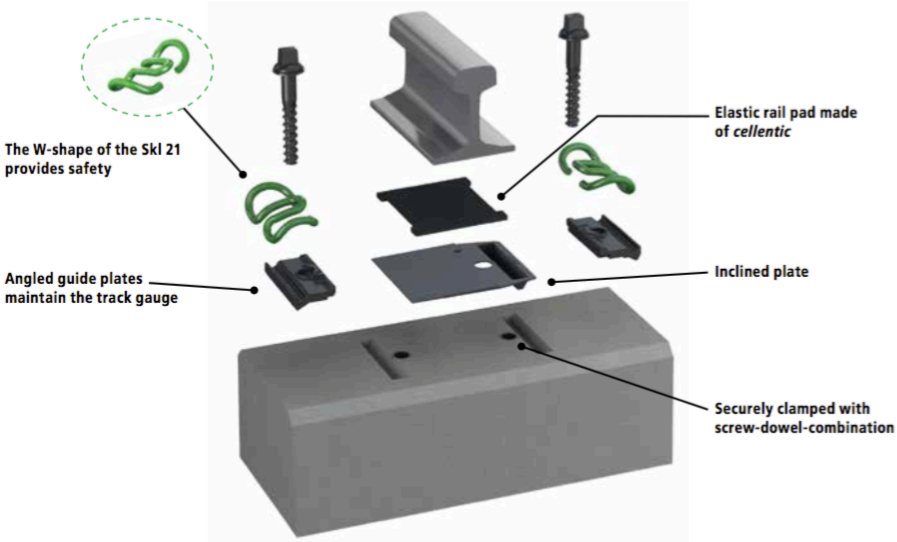


Figure 3.14 – Vossloh's System W 21 T

3.5.2.5 System W 30 T (Vossloh)

System W 30 T, a rail fastening system developed by Vossloh, is on the basis of the W 30 fastening system (Vossloh). It can be adapted to the most different requirements in the field of ballasted track construction; for instance, by inclined plates, that allow rail inclination of 1:20 or 1:40. As shown in the figure below, the system consists of the following components:

1. 2 W-shapes of the Skl 30;
2. 2 angled guide plates;
3. 1 elastic rail pad made of cellentic;
4. 1 inclined plate;
5. 1 securely clamped with screw-dowel-combination.

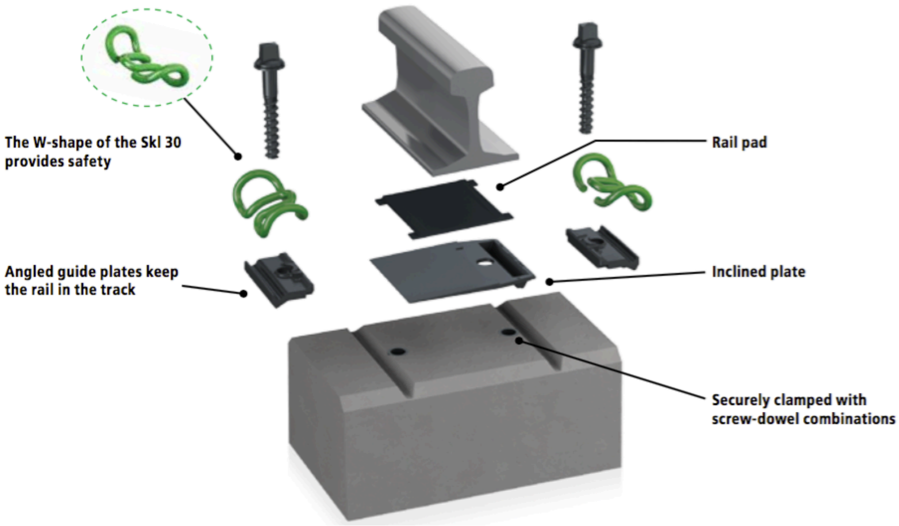


Figure 3.15 – Vossloh's System W 30 T

3.5.2.6 System 300 W (Vossloh)

System 300 W, a rail fastening system developed by Vossloh, is on the basis of the approved 300 fastening system (Vossloh). Built of modules, it can be adapted to different requirements. It provides a solution for application in switches for slab tracks for both high speed and conventional rail. Reference objects for their application can be found in China, in the Channel Tunnel and in Germany (German Unity Transport Project). As shown in the figure below, compared with System W 21 T and W 30 T, the 300 W system consists of more components:

1. 2 W-shapes of the Skl 15;
2. 2 angled guide plates;
3. 2 double coiled spring washer;
4. 2 support brackets;
5. 2 groove shim;
6. 1 rail pad;
7. 1 steel plate ensuring optimum load distribution;
8. 1 highly-elastic intermediate plate for low vibration;
9. 1 intermediate plate;
10. 1 securely clamped with screw-dowel-combination.

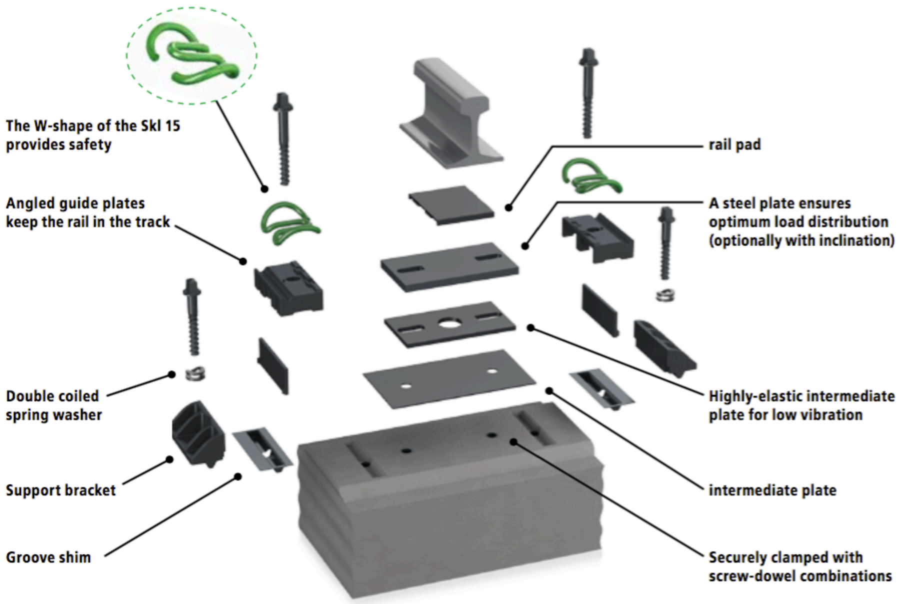


Figure 3.16 – Vossloh's System 300 W

3.5.2.7 Boltless checkrail (Schwihag)

Schwihag has developed a boltless checkrail fastening system. The simple clamping device enables efficient installation and significantly reduces the time required to install guardrails and check rails. It has the following features:

- No drilling in the check rail profile;
- No problem with longitudinal misalignment between checkrail and sleeper or check rail plate;

- Installation time reduced thanks to easy handling;
- Fast and safe replacement of the check rail or guard rails;
- No loose components on the construction site;
- Ideal for guardrails in curved tracks;
- The Schwihag spring clip enables the running rail to be removed without dismantling the checkrail;
- Available for all rail profiles and rail fixings.

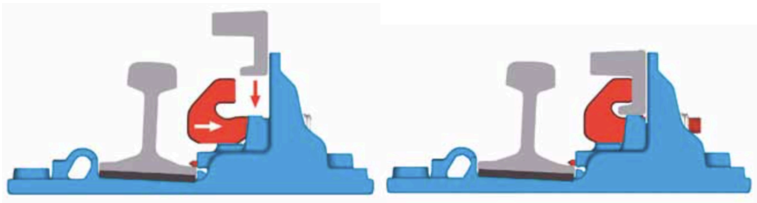


Figure 3.17 – installation of Schwihag's boltless checkrail

4. Actual data to support lean in railway S&C

4.1 Layout of S&C at stations

In order to reduce excessive maintenance work due to unnecessary S&C, the choices regarding the installation of S&C at stations will be discussed in the current project. Evaluation will be performed to decide whether to keep layouts of S&C with redundancy in case of a fault, or to minimize the number of S&C to avoid excessive maintenance.

The layout of S&C along the case study lines has been collected in various appendixes as summarized below.

4.1.1 Layouts of S&Cs at stations along Fevzipaşa-Narlı Line

See Appendix 1.

4.1.2 Layouts of S&Cs at stations along Narlı-Malatya Line

See Appendix 2.

4.1.3 Layouts of S&Cs at stations along Iskenderun-Erzin Line

See Appendix 3.

4.1.4 Layouts of S&Cs at stations along Malatya-DivriğI Line

See Appendix 4.

4.1.5 Layouts of S&Cs at stations along Toprakkale-Ayran Line

See Appendix 5.

4.1.6 Layouts of S&Cs at stations in Slovenia

See Appendix 6.

4.2 Time and resources required for replacement of S&C

4.2.1 Data from IMs outside the NeTIRail-INFRA

The following tables provide the data about replacement of S&C using various methods in different IMs. These data include detail procedure of replacement of S&C, the cost of workforce, work time and machinery, as investigated in the MAINLINE project (MAINLINE, 2014).

Time and resources required according to method used		Pre-assembled S&C							Modular S&C
		Crane	Excavators	Crane	Crane	Excavators	Indep. cranes (UWG system)	Crane-beam (DESEC)	
		DB	TCDD	JBV	TRV	COMSA	MAV	SKANSKA	NR
A. Pre-renewal works									
A.1 Preparation of storage areas		1 shift (8h)							
A.2 Transport of materials									
A.3 Assembly of the new switch in panels in the storage area		2 shift (16h)							
A.4 Topographic works previous to installation		1 shift (8h)							
Total hours (A1+A2+A3+A4)		32h							16h
Work force	A1+a2	2 + 2 (safety)							
	A3	6 + 2 (safety)							
	A4	2 (topography) + 2 (safety)							
Machinery required	A1	Excavator + Dump truck							
	A2	2 vehicles (van)							1 vehicle
	A3	Excavator							Excavator + Dump truck
	A4	Topographic equipment							

Time and resources required according to method used	Pre-assembled S&C							Modular S&C
	Crane	Excavators	Crane	Crane	Excavators	Indep. cranes (UWG system)	Crane-beam (DESEC)	
	DB	TCDD	JBV	TRV	COMSA	MAV	SKANSKA	NR
B. REMOVAL OF THE OLD SWITCH AND SITE PREPARATION (Beginning of track possession)								
B.1 Dismantling of the old switch (including dismantling of signaling and points machines) + B.2a Removal of upper part of the ballast layer		3/4h(wooden/ concrete sleepers)	4h		3h		5h	
B.1 Dismantling of the old switch (including dismantling of signalling and points machines) + B.2b Removal of complete layer of old ballast	4h	4/5h(w/c)	6h	2 shifts (16 h) / 9h	6h	4h	9h	1 shift (8h) / 4,5h
Total hours	B1+B2b = 4h	B1+B2a=3/4h (w/c) B1+B2b=4/5h (w/c)	B1+B2a=4h B1+B2b=6h	B1+B2b=9h	B1+B2a=3h B1+B2b=6h	B1+B2b=4h	B1+B2a=5h B1+B2b=9h	B1+B2b=4,5h
Work force	B1+B2b 10 + 4 (safety) + 2(signalling)	B1+B2a/B2b 10 + 2 (safety) + 2(signalling)	B1+B2a/B2b 5+ 2(safety)+ 2 (signalling)	B1+B2a/B2b 8+ 3(safety)+ 3 (signalling)	B1+B2a/B2b 10+ 2(safety)+ 2(signalling)	B1+B2a/B2b 13 + 2 (safety) + 2(signalling)	B1+B2a/B2b 10 + 2 (safety) + 4(signalling)	B1+B2b 6 + 4 (safety) + 2 (signalling)

Time and resources required according to method used		Pre-assembled S&C							Modular S&C
		Crane	Excavators	Crane	Crane	Excavators	Indep. cranes (UWG system)	Crane-beam (DESEC)	
		DB	TCDD	JBV	TRV	COMSA	MAV	SKANSKA	NR
Machinery required	B1	Crane	2 excavators	Mobile crane	Kirow crane	2 rail/road excavators	Geismar UWG system, Flatbed wagons + loco (for UWG transport)	Crane-beam, special bogies or flat wagons + loco (for Desec transport)	Kirow crane
	B2a		Excavator + Front loader + Dump truck	Front loader + Dump truck		Front loader + Excavator + Dump truck		Front loader + Excavator + Hopper wagons+loco	
	B2b	Excavator + Front loader + Dump truck + Grader (optional) + Roller + Hopper wagons+loco			Excavator + Front loader + Dump truck + Grader (optional) + Roller + Hopper wagons+loco	Front loader + Excavator + Hopper wagons+loco - Roller	Excavator + Hopper wagons+loco / dump truck + Roller	Front loader + Excavator + Hopper wagons+loco + Grader + Roller	Automated ballast collector + Hopper wagons+loco + Grader + Roller

<table>
<tr><th rowspan="3">Time and resources required according to method used</th><th colspan="7">Pre-assembled S&C</th><th rowspan="2">Modular S&C</th></tr>
<tr><th>Crane</th><th>Excavators</th><th>Crane</th><th>Crane</th><th>Excavators</th><th>Indep. cranes (UWG system)</th><th>Crane-beam (DESEC)</th></tr>
<tr><th>DB</th><th>TCDD</th><th>JBV</th><th>TRV</th><th>COMSA</th><th>MAV</th><th>SKANSKA</th><th>NR</th></tr>
<tr><td colspan="9">C. Installation of the new switch</td></tr>
<tr><td>C.1 Placing geogrid and adding new ballast</td><td rowspan="2">4h</td><td>1h (no geo.)</td><td>4h</td><td rowspan="5">2 shifts (16h)/ 9h(C1+C2+C4 +C5)
+
2 shifts (16h) / 9h (C3b)</td><td>4h</td><td>4h</td><td>6h</td><td rowspan="5">1 shift (8h) / 4,5 h (C1+C2+C4+C5) + 2shifts (16h) / 9h (C3b)</td></tr>
<tr><td>C.2 Laying and assembly of the new switch panels +
C.3a Clamping</td><td rowspan="3">5/6 h (w/c) (C2+C3a+C4)
or
10/11h (w/c) (C2+C3b+C4)</td><td rowspan="3">5h</td><td rowspan="3">5h
(C2+C3a+C4)</td><td rowspan="5">5h
(C2+C3a+C4+ C5+C6)</td><td rowspan="3">5h
(C2+C3a+C4)</td></tr>
<tr><td>C.2 Laying and assembly of the new switch panels +
C.3b Welding and stressing</td><td></td></tr>
<tr><td>C.4 Initial track geometry restoration</td><td rowspan="3">3h</td></tr>
<tr><td>C.5 Control system commissioning</td><td>2h</td><td rowspan="2">24h</td><td rowspan="2">3h</td><td rowspan="2">3h</td></tr>
<tr><td>C.6 Final commissioning and testing</td><td>1h</td><td>3h</td><td>3h</td></tr>
<tr><td>C.7 Dynamic Track Stabilizer</td><td></td><td>15min</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Time and resources required according to method used	Pre-assembled S&C							Modular S&C
	Crane	Excavators	Crane	Crane	Excavators	Indep. cranes (UWG system)	Crane-beam (DESEC)	
	DB	TCDD	JBV	TRV	COMSA	MAV	SKANSKA	NR
Total hours	C1+C2+C3a+C5+C6+C7 = 7h	C1+C2+C3a+C4 6/7 h (w/c) C1+C2+C3b+C4 11/12 h (w/c) C5+C6+C7 3,25 h	C1+C2+C3a+C4+C5 9h C6 24 h	C1+C2+C3b+C4+C5 18 h C6 3h	C1+C2+C3a+C4 9h C5+C6 3h	C1+C2+C3a+C4+C5+C6 9h	C1+C2+C3a+C4 11 h C5+C6 3h	C1+C2+C3b+C4+C5 13,5 h C6 3h
Work force	C1+C2+C3a+C5+C6+C7 = 10+2(safety)+2(signaling) C6 = 1 (permanent way engineer)	C1+C2+C3a+C5+C6+C7 10 +2 (safety) + 2(signalling) +1 (permanent way engineer)	C1+C2+C3a+C4+C5+C6 8+1 (safety) + 4 (signalling)	C1+C2+C3b+C4+C5 10 + 3 (safety) + 5 (signalling) +2 (welding) C6 2 (permanent way engineers)	C1+C2+C3a+C4+C5+C6 10 +2 (safety) + 2(signalling) +1 (permanent way engineer)	C1+C2+C3a+C4+C5+C6 12 +2 (safety) + 2(signalling) + 1 (permanent engineer)	C1+C2+C3a+C4+C5+C6 10 +2 (safety) + 4(signalling)	C1+C2+C3b+C4+C5 6 + 3 (safety) + 3 (signalling) +2 (welding) C6 2 (permanent way engineers)

Time and resources required according to method used		Pre-assembled S&C							Modular S&C
		Crane	Excavators	Crane	Crane	Excavators	Indep. cranes (UWG system)	Crane-beam (DESEC)	
		DB	TCDD	JBV	TRV	COMSA	MAV	SKANSKA	NR
Machinery required	C1	Hopper wagons+loco (for new ballast) + Front loader+ Roller	Hopper wagons+loco (for new ballast), Grader+ Roller	Hopper wagons+loco (for new ballast) + Front loader+ Roller	Hopper wagons+loco (for new ballast) + Front loader+ Roller	Hopper wagons+loco (for new ballast) + Front loader+ Roller	Hopper wagons+loco (for new ballast) + Front loader+ Roller	Hopper wagons+loco (for new ballast) + Front loader+ Roller	Hopper wagons+loco (for new ballast) + Front loader+ Roller
	C2	Mobile Crane	2 Excavators	Mobile Crane	Mobile Crane	2 Rail/Road excavators	Geismar UWG system+ Flatbed wagons + loco (for UWG transport)	Crane-beam (Desec) + Special bogies or flat wagons + loco (for Desec transport)	Tilting wagons+loco + Kirow Crane
	C4	S&C tamping machine+ Regulator (optional)+ Topographic equipment	S&C tamping machine + Ballast regulator + Topographic equipment	S&C tamping machine+ Regulator (optional)+ Topographic equipment	S&C tamping machine+ Regulator (optional)+ Topographic equipment	S&C tamping machine + Ballast regulator + Topographic equipment	S&C tamping machine + Topographic equipment	S&C tamping machine + Ballast regulator + Topographic equipment	S&C tamping machine+ Regulator (optional)+ Topographic equipment
	C7		DTS						

Time and resources required according to method used		Pre-assembled S&C							Modular S&C
		Crane	Excavators	Crane	Crane	Excavators	Indep. cranes (UWG system)	Crane-beam (DESEC)	
		DB	TCDD	JBV	TRV	COMSA	MAV	SKANSKA	NR
D. POST-RENEWAL ACTIVITES (Opening of the line with temporary speed restriction)									
D.1 Welding and stress release		1 shift (8h)	1 shift (8h)	3 shifts (21h)		1 shift (8h)	1 shift (8h)	7h	
D.2 Final track restoration		1 shift (8h)		1 shift (8h)	1 shift (8h)	1 shift (8h)	1 shift (8h)		1 shift (8h)
D.3 Final inspection and acceptance			1h inspect. During 7 days						
Total hours	D1	16h	15h	29h		16h	16h	7h	
	D2				8h				8h
	D3								
Work force	D1	4 (welders) + 2 (safety)	4 (welders) + 2 (safety)	2(welders) + 1 (safety)		4 (welders) + 2 (safety)	4 (welders) + 2 (safety)	10 + 2 (safety) + 4(signalling) + 2(topograph) + 4 (welders))	
	D2	2(topograph) + 2 (safety) + 2 (perman. way engineers)		2 (topograph) + 1 (safety) + 1 (perman. way engineer)	2 (topograph) + 2 (safety) + 2 (perman. way engineers)	2 (topograph) + 2 (safety) + 2 (perman. way engineers)	2 (topograph) + 2 (safety) + 2 (perman. way engineers)		2 (topograph) + 2 (safety) + 2 (perman. way engineers)
	D3		1 (permanent way engineer)						
Machinery required	D2	S&C Tamper+ Ballast regulator + Topographic equipment	S&C Tamper+ Ballast regulator + Topographic equipment	S&C Tamper+ Ballast regulator + Topographic equipment	S&C Tamper+ Ballast regulator + Topographic equipment	S&C Tamper+ Topographic equipment	S&C Tamper+ Topographic equipment	S&C Tamper+ Ballast regulator + Topographic equipment + Hopper wagons+loco	S&C Tamper+ Ballast regulator + Topographic equipment

4.2.2 Data from SZ

This section provides actual data of the replacement of S&C from SZ.

1. The location of this repair or renewal
    a. Freight station Koper (about 120 (basic) switches, about 15 crossings)
    b. Hrpelje-Kozina (about 5 or 6 (basic) switches)
2. The accessibility to this site, in terms of transferring or using heavy machinery like lifts and cranes: good
3. The labour cost per hour used to do the repair or renewal: 3.000,00 EUR

The replacement of S&C consists of the following four phases, according to the data structure of the previous section:

A. Pre-renewal works;
B. Removal of the old switch and site preparation;
C. Installation of the new switch;
D. Post-renewal activities (opening of the line with temporary speed restriction).

The work time[2], work force and resources required of each phase are detailed as follows.

A. Pre-renewal works

Phase	Work force	Work time	Machinery
A1. Preparation of storage areas	4 workers + 1 security guard	1 shift (8h)	excavator + truck
A2. Transport of materials (only components of the switch)	1 security guard	1 shift (8h)	motorized draisine + trailer + two-floor excavator
A3. Assembly of the new switch in panels in the storage area	12 workers + 1 security guard	1 shift (8h)	two-floor excavator
A4. Topographic works previous to installation	1 geometrician + 2 workers + 1 security guard	1 shift (8h)	
Total		32h	

[2] Time data hereafter is in general (approximately, average) for basic switches, crossings need some more time.

B. Removal of the old switch and site preparation

Phase	Work force	Work time	Machinery
B1. Dismantling of the old switch, signaling and points machines	12 workers + 1 security guard	4h	motorized draisine + trailer + two-floor excavator
B2a. Removal of upper part of the ballast layer B2b. Removal of complete layer of old ballast	3 workers + 2 security guard	4h	excavator + trucks + bulldozer + roller + bulldozer
B3. Turning off ESSD (electronic signaling safety device) device/system and switch drive (SD)		2h	
B4. Dismantling of off ESSD and SD		2h	
B5. Preparation of the switch and installation of SD		4h	
B6. Measurements of ESSD and SD after installation		2h	
B7. Reconnection and testing of ESSD		2h	
Total		20h	

C. Installation of the new switch

Phase	Work force	Work time	Machinery
C1. Dismantling of the old switch (including dismantling of signaling and points machines)	Taken into account in B1		
C2. Geotextiles, tampon and crushed rocks + Laying and assembly of the new switch panels C3a. Clamping	18 workers + 3 security guard	5h	Bulldozer + Roller + Loader + Trucks + Trailer + Motorized draisine + Two-floor excavator
C3b. Welding	2 welders + 1 worker + 1 security guard	8h	Van
C4. Initial track geometry restoration	1 geometrician + 1 worker + 1 security guard	1h	
C5. Control system commissioning taken into account (included) in B6	Taken into account in B6		
C6. Final commissioning and testing … taken into account (included) in B7	Taken into account in B7		
C7. Directional and height adjusting of the switch with the switch leveling straightener and banking up ballast	2 workers + 1 security guard	2h	Switch leveling straightener + Wagon with ballast
Total		12h[3]	

[3] It is not the sum of all the work time, since works within the replacement of a switch are overlapping.

D. Post-renewal activities (opening of the line with temporary speed restriction)

Phase	Work force	Work time	Machinery
D1. Welding and stress release	13 workers + 2 welders + 1 security guard	8h	Van
D2. Final track restoration	2 workers + 1 security guard	6h	Switch leveling straightener + Wagon with ballast
D3. Final inspection and acceptance	1 geometrician + 1 worker + 1 security guard	2h	
Total		16h	

4.2.3 Data from INTADER and TCDD

Lean technology is in line with lean maintenance techniques as well. Less time for maintenance and reparations, less maintenance/replacement cost are signed in the scope of this philosophy. TCDD has produced the S&Cs transport wagons. Switches will be assembled in the manufactory or storage area and will be transported to the area. Thus, the down time for replacement of S&C will be decreased.

4.2.3.1 Workflow of replacement of S&C with cranes

A. Pre-renewal works
   1. Preparation of storage areas
   2. Transport of materials
   3. Preparation of old switch (If the time is limited, an S&C is divided into 3 parts: switch panel, crossing panel and closure panel) or screwing off rail screws, lubricating, etc.)
   4. Assembly of the new switch near the old switch (next to track)
B. Removal of old switch and site preparation
   1. Dismantling of the old switch
   2. Loading of old switch to wagon
   3. Transport of old switch to storage area
   4. Removal of ballast (sub ballast/upper ballast)
   5. Ballasting
   6. Straighten the layer by excavator
C. Installation of the new switch
   1. Carrying the assembled new switch to the place of old switch
   2. Clamping
   3. Adding of ballast
   4. Dynamic track stabilizer
   5. Track geometry measurement (EN 13231)
   6. If track geometry is in acceptable limits => Speed limitation. Otherwise, => sleepers, rail screws, infrastructure ballast are checked, and repaired.
D. Post renewal activities
   1. Final track restoration
   2. Welding and stressing
   3. Final acceptance and acceptance

4.2.3.2 Workflow of replacement of S&C without cranes

A. PRE-RENEWAL WORKS
   1. Preparation of storage areas
   2. Transport of materials
   3. Preparation of old switch (If the time is limited rail is divided into 3 parts: switch panel, crossing panel, closure panel) or screwing off rail screws, lubricating, etc.)

B. REMOVAL OF OLD SWITCH AND SITE PREPARATION
   1. Dismantling of the old switch
   2. Loading of old switch to wagon
   3. Transport of old switch to storage area
   4. Removal of ballast (sub ballast/ upper ballast)
   5. Ballasting
   6. Straighten the layer by excavator

C. INSTALLATION OF THE NEW SWITCH
   1. Lying out and assembly of the new switch
   2. Clamping
   3. Adding of ballast
   4. Dynamic track stabilizer
   5. Track geometry measurement (EN 13231)
   6. If track geometry is in acceptable limits => Speed limitation. Otherwise, => sleepers, rail screws, infrastructure ballast are checked, and repaired.

D. POST RENEWAL ACTIVITIES
   1. Final track restoration
   2. Welding and stressing
   3. Final acceptance and acceptance

4.2.3.3 Workflow of replacement of S&C with switch transport wagons

A. Pre-renewal works
   1. Assembly of S&C in the storage area
   2. Transport of S&Cs as 3 pieces
   3. Preparation of old switch (If the time is limited rail is divided into 3 parts: switch panel, crossing panel, closure panel) or screwing off rail screws, lubricating, etc.)

B. Removal of old switch and site preparation
   1. Dismantling of the old switch
   2. Loading of old switch to wagons
   3. Transport of old switch to storage area

C. Installation of the new switch
   1. Carrying the assembled new switch to the place of old switch
   2. Clamping
   3. Adding of ballast
   4. Dynamic track stabilizer

D. Post renewal activities
   1. Final track restoration
   2. Welding and stressing
   3. Final acceptance and acceptance

4.3 Climatic data along case study lines in Turkey, Slovenia and Romania

This section provides some historic climatic data along the NeTIRail-INFRA case study lines in Turkey, Slovenia and Romania. These data, collected from (ECA&D), include the number of icy days, maximum and minimum temperatures in each year from as early as 1900 until now. The data show the extreme climatic conditions in the past hundred years, which should be considered in the future choices of infrastructure and maintenance work.

The data collected include:

1. Climate chart with the highest and the lowest temperature, and precipitation monthly;
2. The number of ice days (ID, daily maximum temperature < 0°C);
3. The maximum value of daily maximum temperature (TXx);
4. The minimum value of daily minimum temperature (TNn).

The data below are particularly useful for the choice of lubrication and debris-proof systems in the current task.

4.3.1 Climatic data along case study lines in Turkey

This section provides some historic climatic data collected from 3 Turkish weather stations: Ankara, Malatya and Adana, which respectively locate near the following 3 Turkish case study lines:

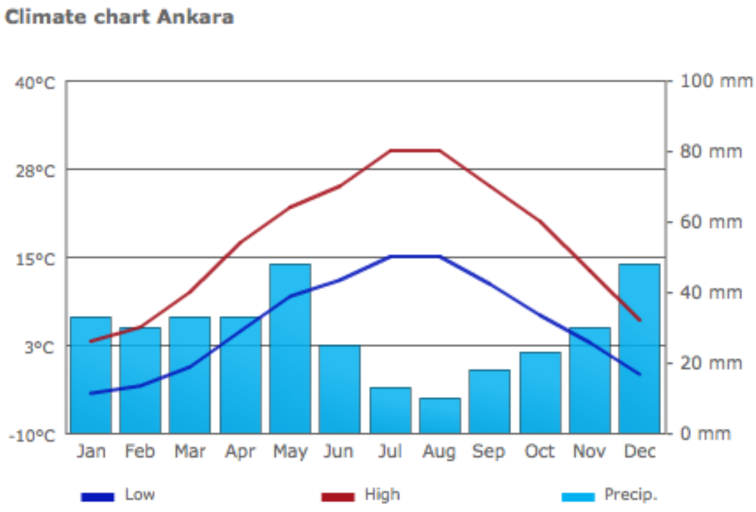
1. Sincan-Marşandiz-Ankara-Kayaş (near Ankara weather station);
2. Divriği-Çetinkaya-Hekimha-Malatya (near Malatya weather station);
3. Malatya-Narlı-Fevzipaşa-Toprakkale-İskenderun (less than 90km from Adana weather station).

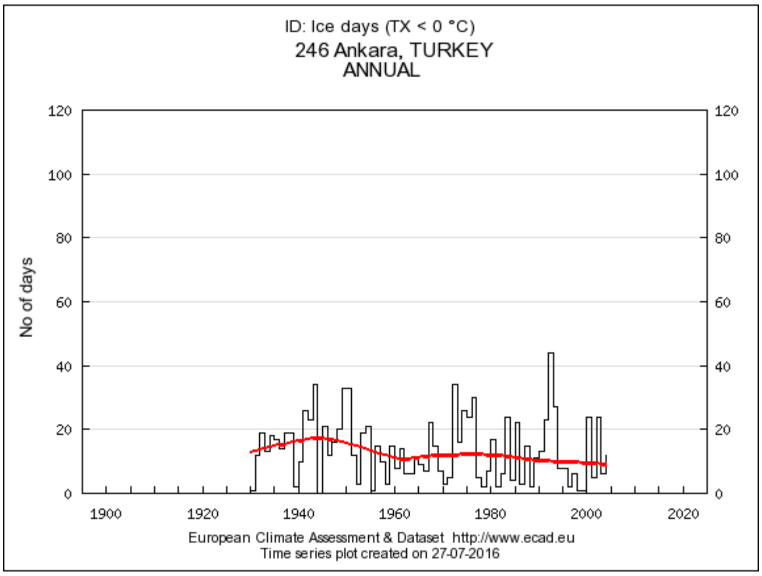
4.3.1.1 Climatic data of Ankara

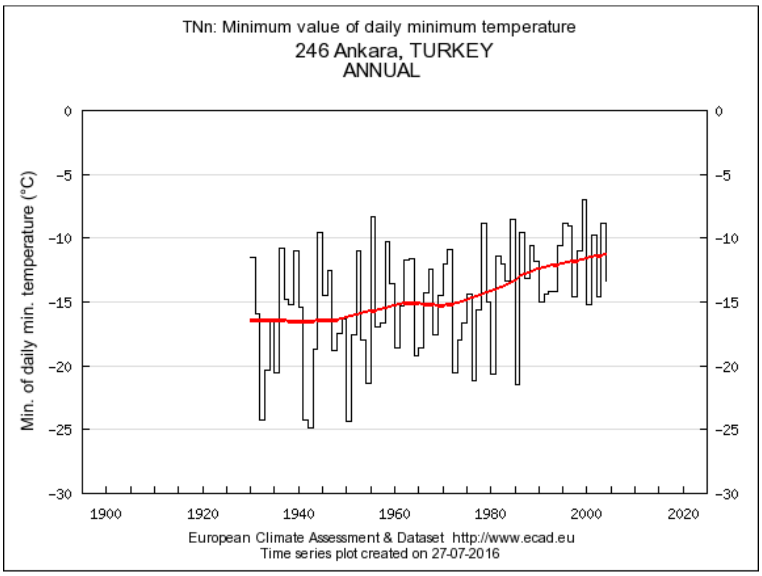
Temperature, Precipitation and sunshine (World climate data) (ECA&D)

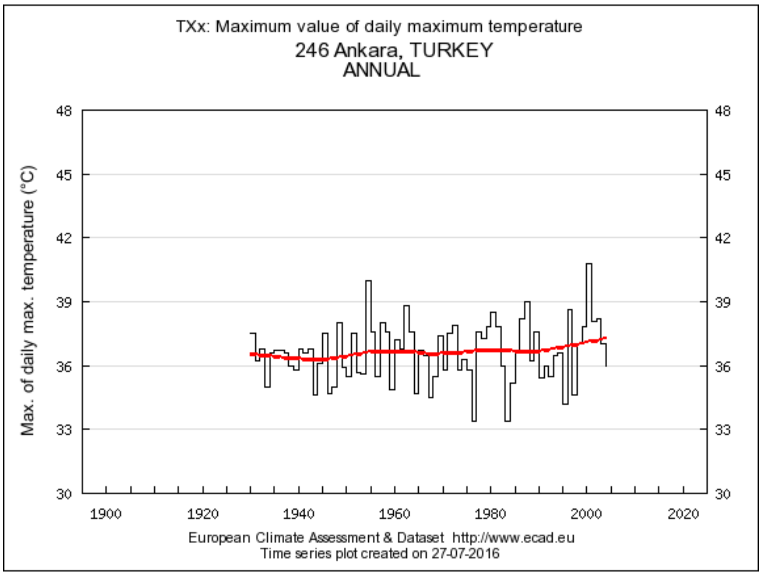
	Jan	Feb	Mar	Apr	May	June
Average high in °C	3	5	10	17	22	25
Average low in °C	-4	-3	-1	4	9	12
Av. precipitation - mm	33	30	33	33	48	25
Days with precip.	8	8	7	7	7	5
Hours of sunshine	96	118	174	210	282	336

	July	Aug	Sep	Oct	Nov	Dec
Average high in °C	30	30	25	20	13	6
Average low in °C	15	15	11	7	3	-2
Av. precipitation - mm	13	10	18	23	30	48
Days with precip.	2	1	3	5	6	9
Hours of sunshine	384	369	291	226	159	96


Climate chart Ankara
40°C
28°C
15°C
3°C
-10°C
100 mm
80 mm
60 mm
40 mm
20 mm
0 mm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Low
High
Precip.

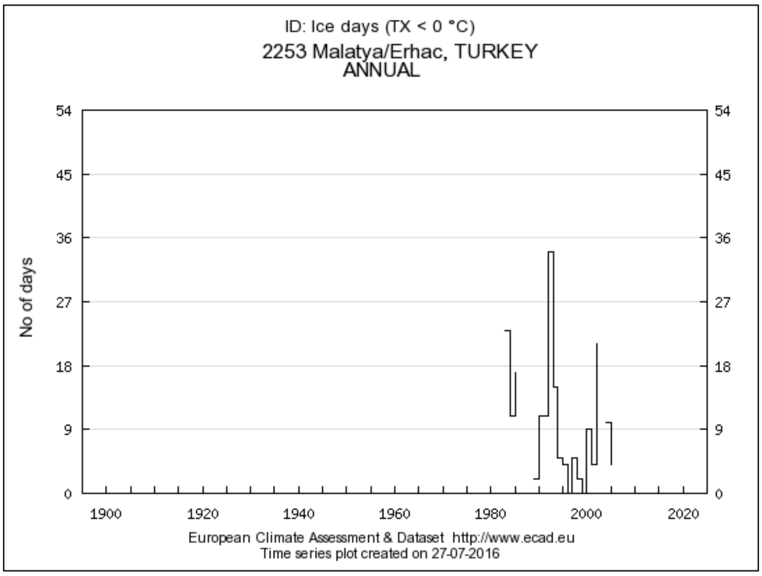

ID: Ice days (TX < 0 °C)
246 Ankara, TURKEY
ANNUAL
No of days
1900 1920 1940 1960 1980 2000 2020
European Climate Assessment & Dataset http://www.ecad.eu
Time series plot created on 27-07-2016

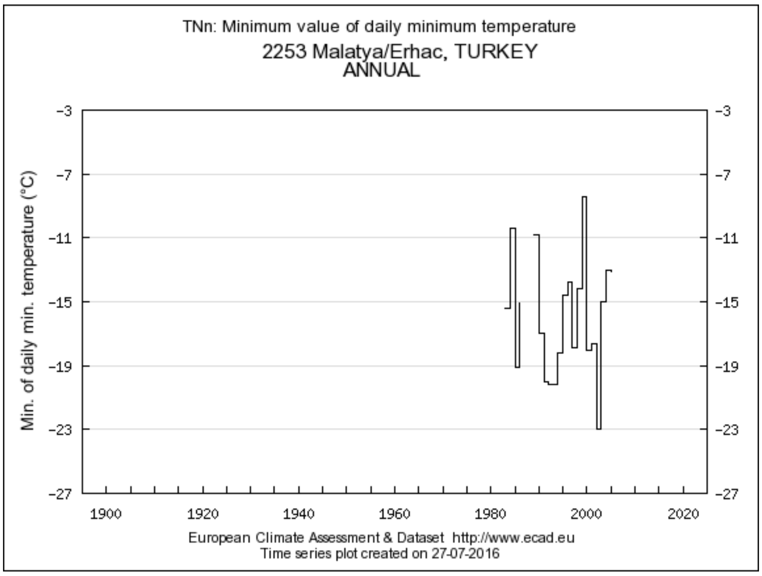

TNn: Minimum value of daily minimum temperature
246 Ankara, TURKEY
ANNUAL
Min. of daily min. temperature (°C)
1900 1920 1940 1960 1980 2000 2020
European Climate Assessment & Dataset http://www.ecad.eu
Time series plot created on 27-07-2016

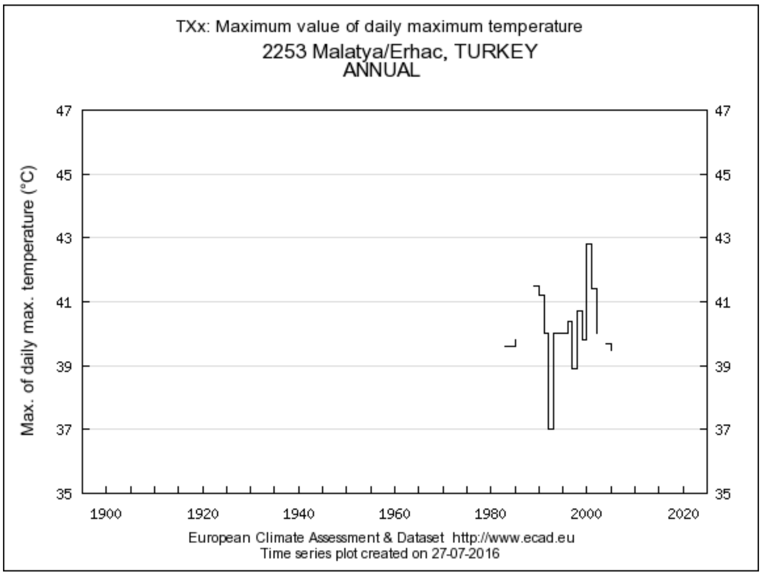


4.3.1.2 Climatic data of Malatya

Temperature (ECA&D)





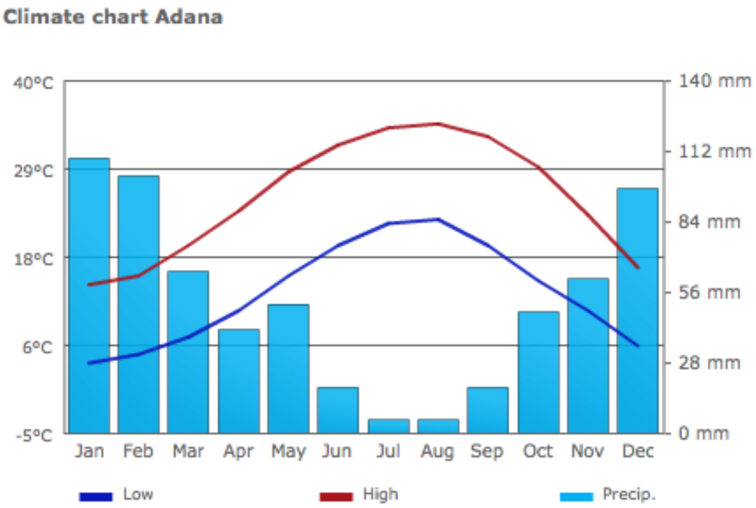


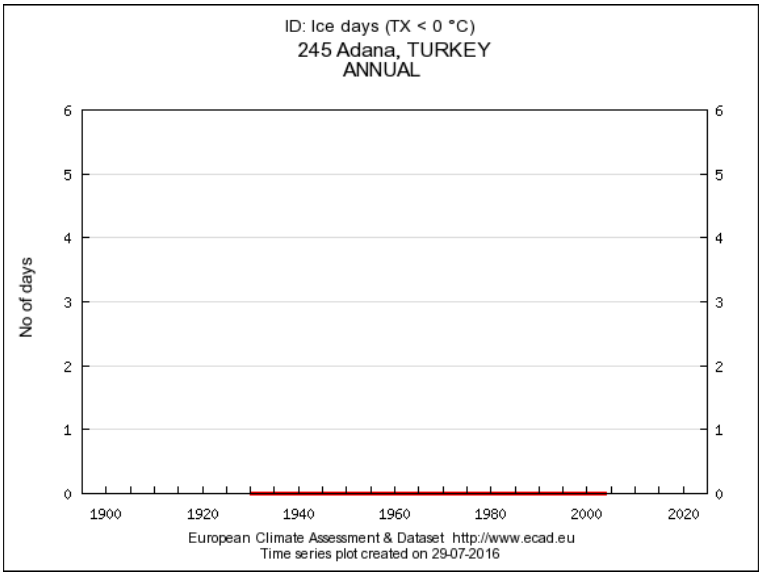
4.3.1.3 Climatic data of Adana

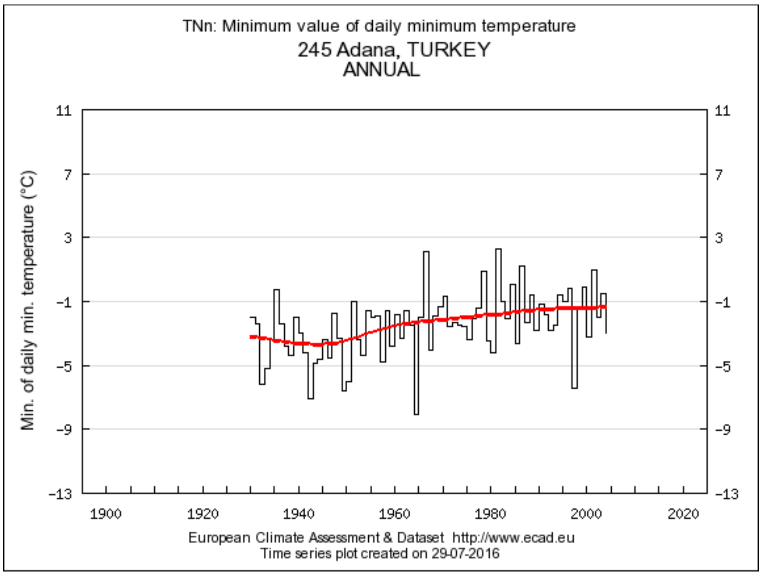
Temperature, Precipitation and sunshine (World climate data) (ECA&D)

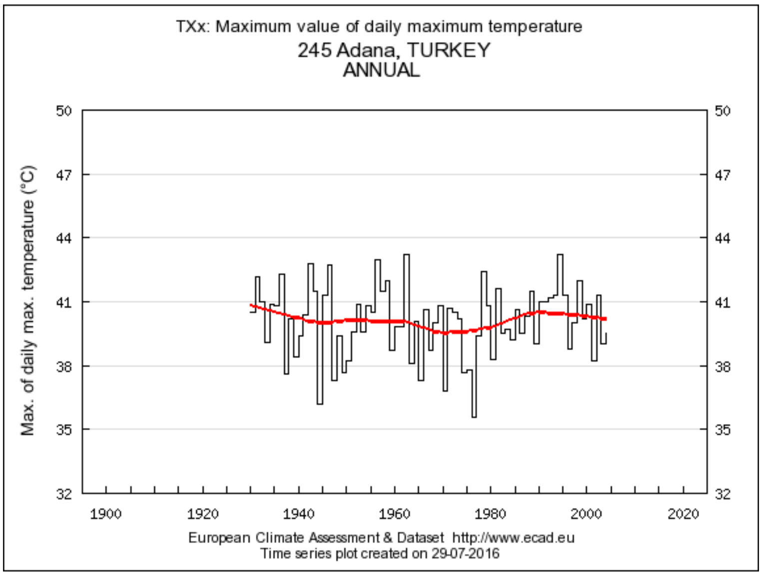
	Jan	Feb	Mar	Apr	May	June
Average high in °C	14	15	19	23	28	32
Average low in °C	4	5	7	11	15	19
Av. precipitation - mm	109	102	64	41	51	18
Days with precip.	8	7	6	5	4	2
Hours of sunshine	155	168	208	243	310	348

	July	Aug	Sep	Oct	Nov	Dec
Average high in °C	34	34	33	29	23	16
Average low in °C	22	22	19	14	11	6
Av. precipitation - mm	5	5	18	48	61	97
Days with precip.	1	1	1	4	5	7
Hours of sunshine	372	363	306	260	192	149


Climate chart Adana
40°C
29°C
18°C
6°C
-5°C
140 mm
112 mm
84 mm
56 mm
28 mm
0 mm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Low
High
Precip.


ID: Ice days (TX < 0 °C)
245 Adana, TURKEY
ANNUAL
No of days
1900 1920 1940 1960 1980 2000 2020
European Climate Assessment & Dataset http://www.ecad.eu
Time series plot created on 29-07-2016


TNn: Minimum value of daily minimum temperature
245 Adana, TURKEY
ANNUAL
Min. of daily min. temperature (°C)
1900 1920 1940 1960 1980 2000 2020
European Climate Assessment & Dataset http://www.ecad.eu
Time series plot created on 29-07-2016



4.3.2 Climatic data along case study lines in Slovenia

This section provides some historic climatic data collected from 2 Slovenian weather stations: Ljubljana Bezig and Postojna, and 1 Italian station Trieste, which respectively locate near the following 3 Slovenian case study lines:

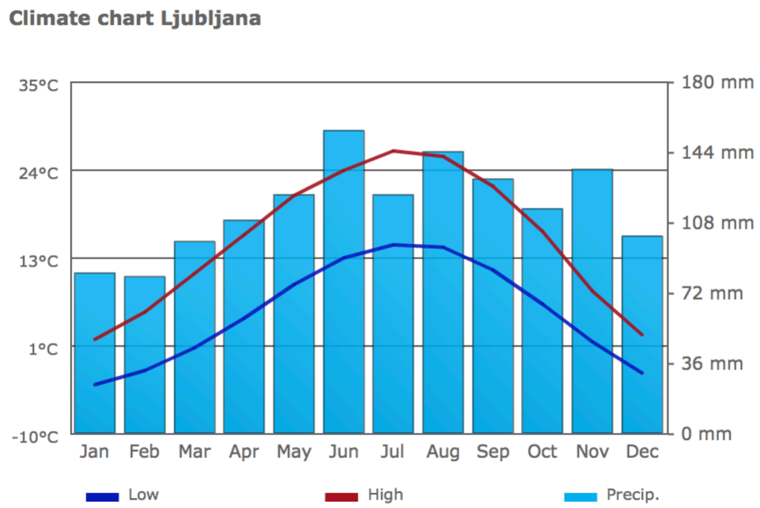
1. Ljubljana – Kamnik (near Ljubljana Bezig weather station)
2. Pivka – Ilirska Bistrica (10 km from Postojna weather station)
3. Divača – Koper (less than 20 km from Trieste weather station)

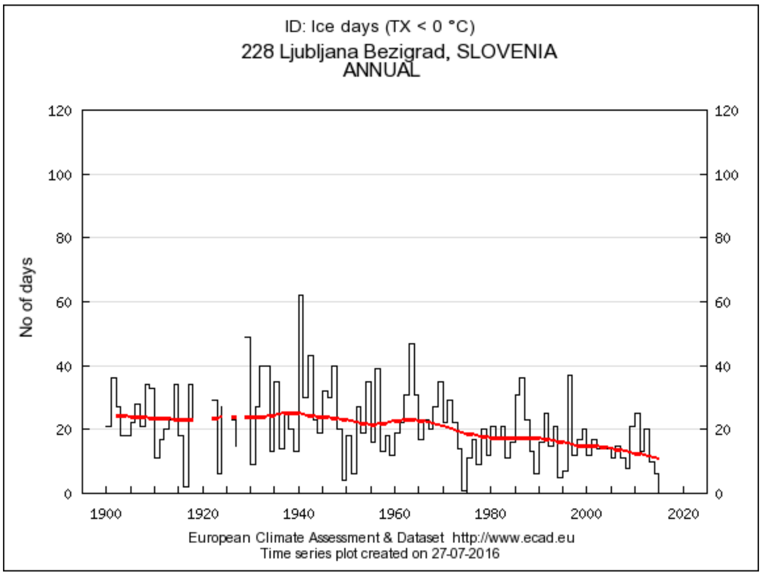
4.3.2.1 Climatic data of Ljubljana

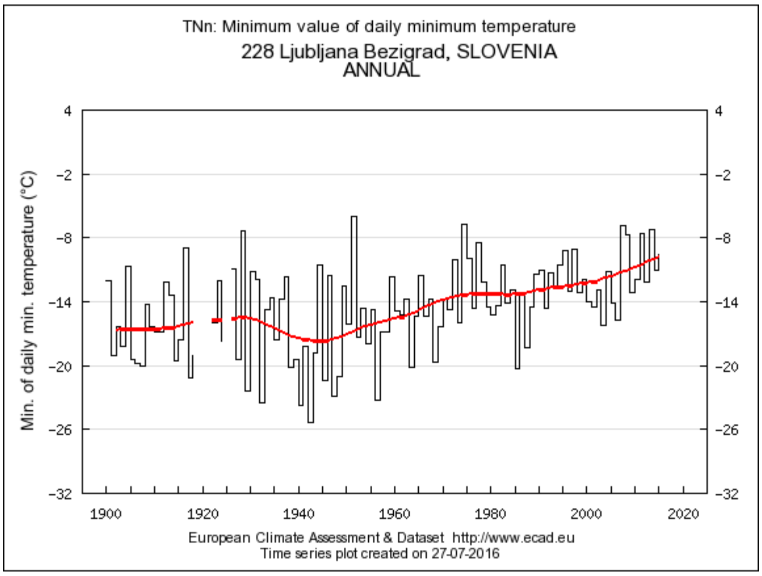
Temperature, Precipitation and sunshine (World climate data) (ECA&D)

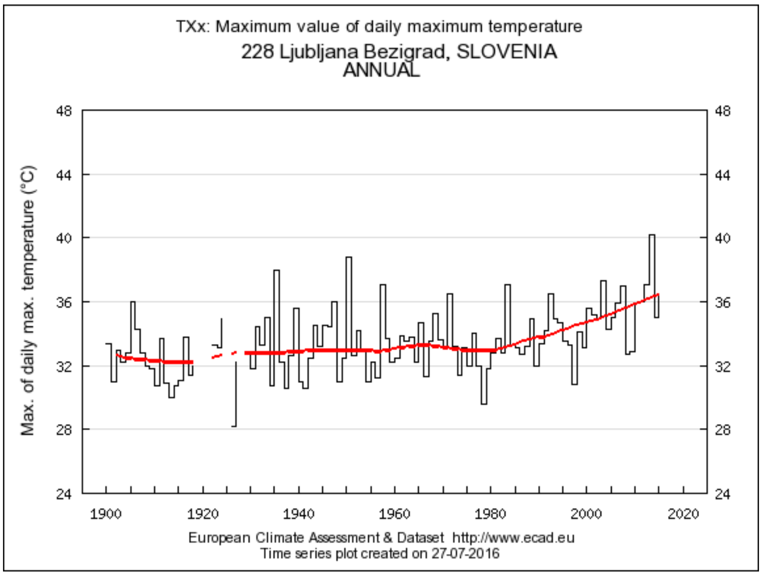
	Jan	Feb	Mar	Apr	May	June
Average high in °C	2	6	10	15	20	24
Average low in °C	-4	-2	1	5	9	12
Av. precipitation - mm	82	80	98	109	122	155
Days with precip.	9	8	9	11	12	12
Hours of sunshine	47	85	128	162	210	221

	July	Aug	Sep	Oct	Nov	Dec
Average high in °C	26	25	22	16	8	3
Average low in °C	14	14	11	7	2	-2
Av. precipitation - mm	122	144	130	115	135	101
Days with precip.	10	10	8	8	9	9
Hours of sunshine	260	230	164	116	56	37


Climate chart Ljubljana
35°C
24°C
13°C
1°C
-10°C
180 mm
144 mm
108 mm
72 mm
36 mm
0 mm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Low
High
Precip.

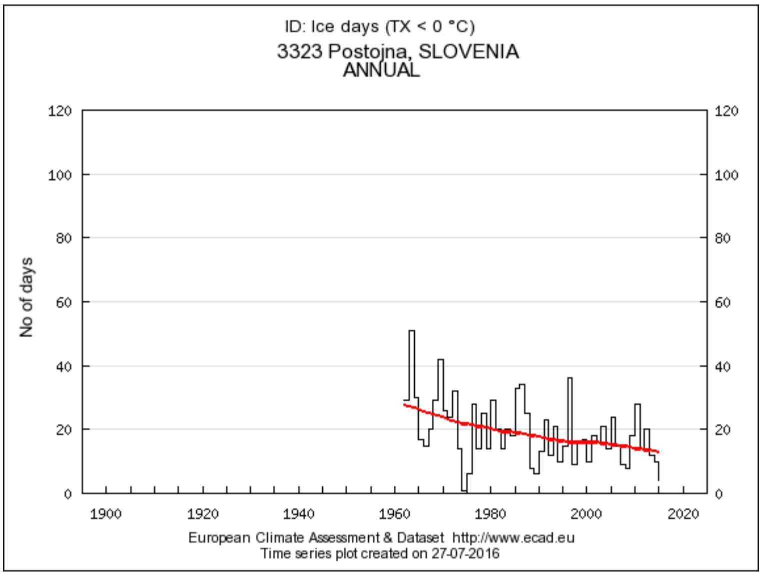

ID: Ice days (TX < 0 °C)
228 Ljubljana Bezigrad, SLOVENIA
ANNUAL
No of days
1900 1920 1940 1960 1980 2000 2020
European Climate Assessment & Dataset http://www.ecad.eu
Time series plot created on 27-07-2016

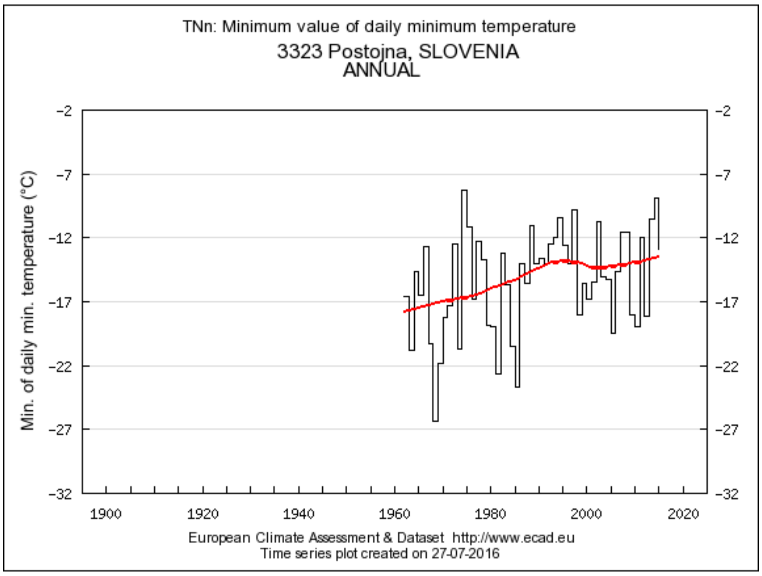

TNn: Minimum value of daily minimum temperature
228 Ljubljana Bezigrad, SLOVENIA
ANNUAL
Min. of daily min. temperature (°C)
1900 1920 1940 1960 1980 2000 2020
European Climate Assessment & Dataset http://www.ecad.eu
Time series plot created on 27-07-2016

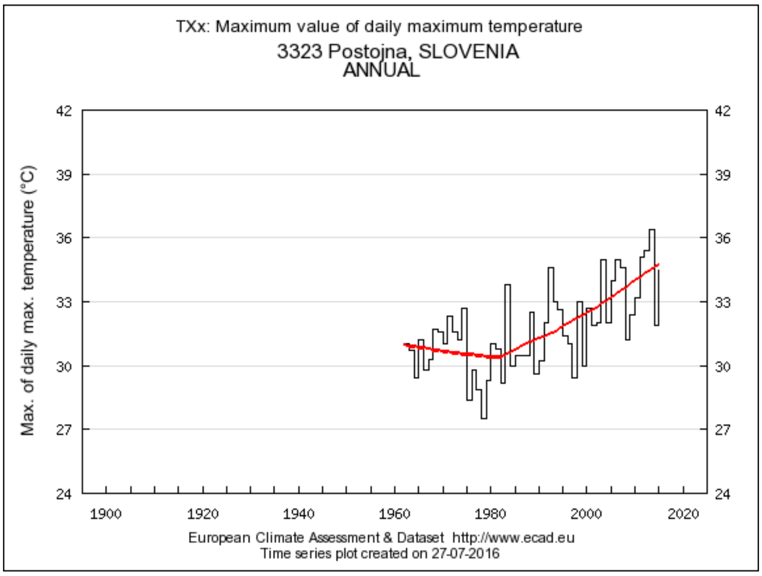


4.3.2.2 Climatic data of Postojna

Temperature (ECA&D)





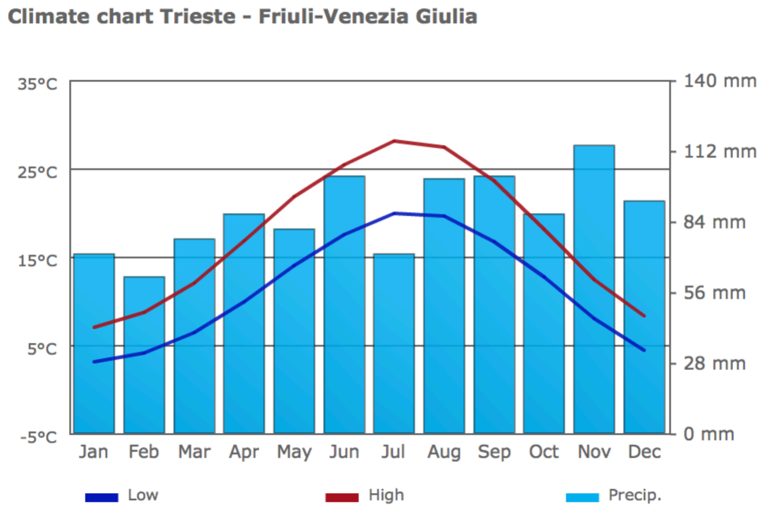


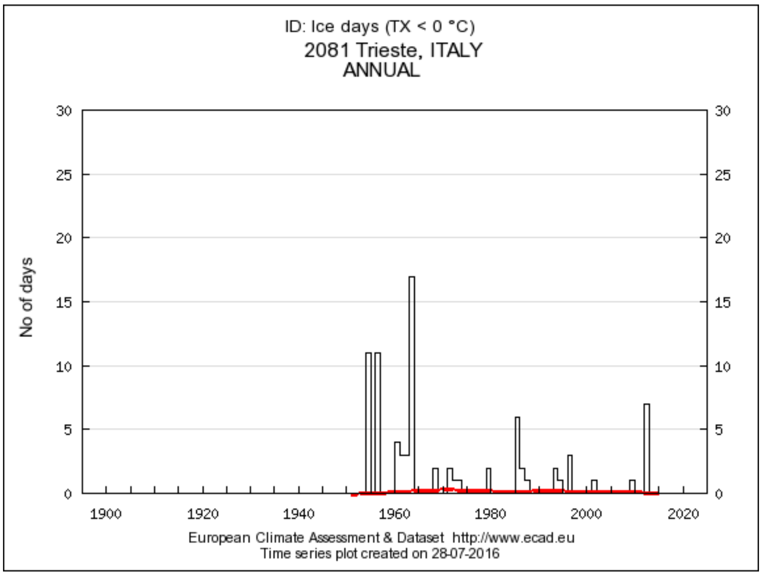
4.3.2.3 Climatic data of Trieste

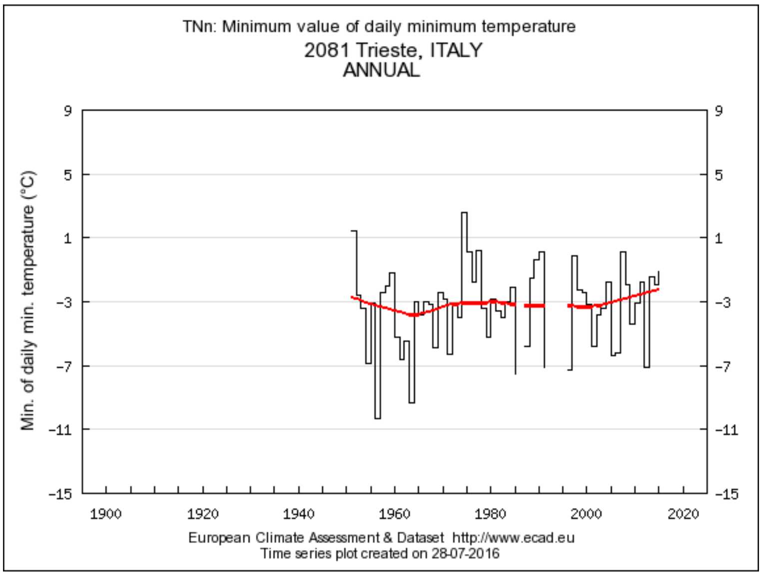
Temperature, Precipitation and sunshine (World climate data) (ECA&D)

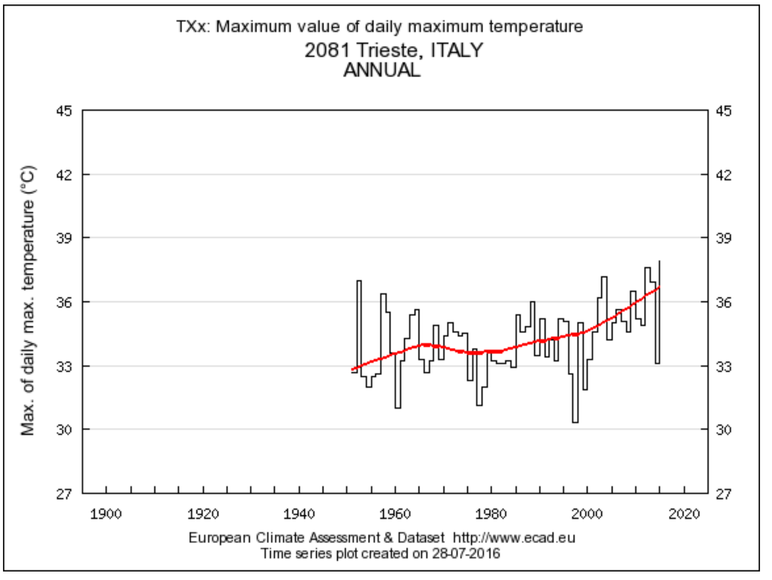
	Jan	Feb	Mar	Apr	May	June
Average high in °C	7	9	12	17	22	25
Average low in °C	3	4	6	10	14	18
Av. precipitation - mm	71	62	77	87	81	102
Days with precip.	8	8	8	9	9	10
Hours of sunshine	96	118	143	177	226	243

	July	Aug	Sep	Oct	Nov	Dec
Average high in °C	28	27	24	18	12	8
Average low in °C	20	20	17	13	8	4
Av. precipitation - mm	71	101	102	87	114	92
Days with precip.	7	8	8	8	10	9
Hours of sunshine	288	260	210	167	99	84


Climate chart Trieste - Friuli-Venezia Giulia
35°C
25°C
15°C
5°C
-5°C
140 mm
112 mm
84 mm
56 mm
28 mm
0 mm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Low
High
Precip.


ID: Ice days (TX < 0 °C)
2081 Trieste, ITALY
ANNUAL
No of days
30
25
20
15
10
5
0
1900 1920 1940 1960 1980 2000 2020
European Climate Assessment & Dataset http://www.ecad.eu
Time series plot created on 28-07-2016


TNn: Minimum value of daily minimum temperature
2081 Trieste, ITALY
ANNUAL
Min. of daily min. temperature (°C)
9
5
1
−3
−7
−11
−15
1900 1920 1940 1960 1980 2000 2020
European Climate Assessment & Dataset http://www.ecad.eu
Time series plot created on 28-07-2016

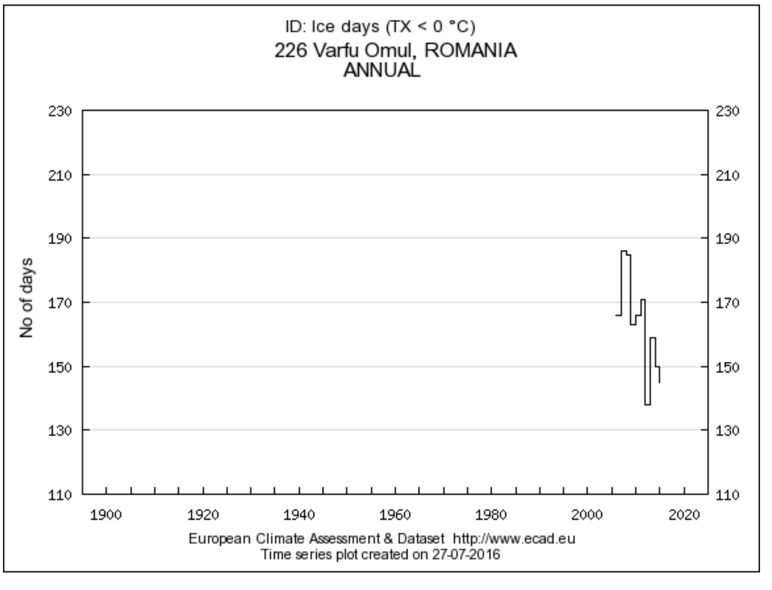


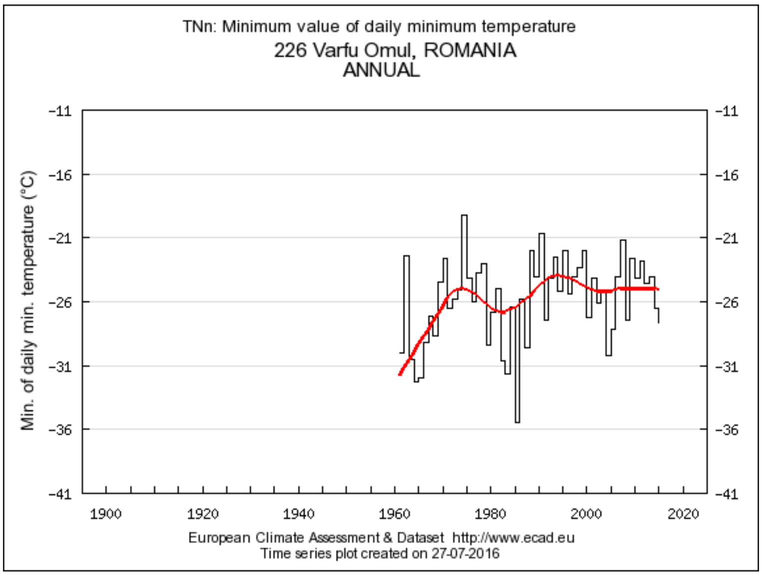
4.3.3 Climatic conditions along Romanian case study lines

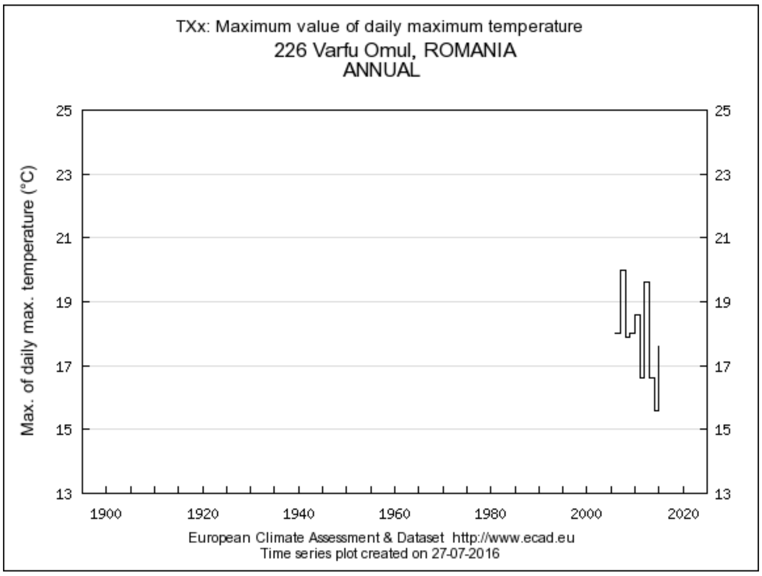
This section provides some historic climatic data collected from Romanian weather station Valfu Omu, which locates 10 km from the Romanian case study line.

4.3.3.1 Climatic data of Valfu Omu

Temperature (ECA&D)







4.4 Turnout failures

4.4.1 Turnout failures in Slovenia

See Appendix 6.

4.5 Traffic volume

This section provides the data about the traffic volume of the case study lines in the current task, collected (NeTIRail, 2016).

The NeTIRail Consortium line selection is displayed in the table below. Lines are characterized by their length and yearly statistics (ST: single track; DT: double track; PT: passenger trains; MP: millions of passengers; FT: freight trains; Mt: millions of freight net tonnes). Data reflect 2014 situation.

Category \ Country	Romania	Slovenia	Turkey
Busy, capacity-limited passenger railway	N/A	Ljubljana – Kamnik 23.6 km ST, diesel 10 276 PT – 0.4 MP 506 FT – 0.08 Mt	Ankara - Sincan 37.0 km 3-4T, 25kV~ 196 599 PT – 16 MP 7 174 FT –
Under-utilised secondary line	Bartolomeu-Zărneşti 23.9 km ST, diesel 10 220 PT – 0.6 MP 192 FT – 0.37 Mt	Pivka – Ilirska Bistrica 24.5 km ST, 3 kV = 4 141 PT – 0.02 MP 1 451 FT – 0.57 Mt	Divriği- Malatya 207 km ST, 25kV~ 5 691 PT – 0.49 MP 22 597 FT –
Freight dominated route	N/A	Divača – Koper 48.0 km ST, 3 kV = 4 420 PT* – 0.1 MP 20 837 FT – 11.04 Mt	Malatya- İskenderun 374 km ST, 25kV~ 3 593 PT – 0.58 MP 38 088 FT –

Table 4 – Summary of selected lines

** Number of passenger trains in 2013. In 2014 the ice was on the line Ljubljana-Divača, which was reflected in the traffic on the line Divača-Koper, so the number of passenger trains is lower than in previous years.*

We see that "under-utilized secondary line" is an elastic concept, much depending on the line characteristics (defining the potential utilisation) and the local context (yielding the actual utilisation).

5. Methodology for lean in railway S&C

This chapter discusses the methodology for lean in railway S&C. The railway industry has a lot of differences from the automotive sector, where the lean manufacturing was first developed. The following sections will explain review the some lean concepts and evaluate possible opportunities for optimization in S&C.

5.1 Introduction to lean technique

Lean manufacturing is a philosophy first observed in the production process of Toyota. Then, the lean technique has been successfully developed and applied in some other industries, such as service providers, administrative offices, and software engineering. The goal of lean production is to minimize waste and maximize flow.

Waste is a term used in Lean terminology to mean any activity or process that does not add value to the customer. To improve the process for renewal of S&Cs, all the process should be mapped and revealed. The lean philosophy recognizes the following seven types of waste:

- Transport (moving products that are not actually required to perform the processing);
- Inventory (all components, work in process, and finished product not being processed);
- Motion (people or equipment moving or walking more than is required to perform the processing);
- Waiting (waiting for the next production step, interruptions of production during shift change);
- Overproduction (production ahead of demand);
- Over Processing (resulting from poor tool or product design creating activity);
- Defects (the effort involved in inspecting for and fixing defects).

They are often written in short form of “TIMWOOD”.

The focus of lean systems can be defined as more reliable equipment, just in time production and material control techniques, balanced production, consistent improvement processes, control techniques for quality, stopping the manufacturing in case of any problem, and developing human systems to support technical processes.

By adopting lean manufacturing techniques, organizations can improve the overall productivity, market share, the speed of producing new product and serve to market, reducing manufacturing costs and labour cost, and reducing non value added processes and operations.

In order to perform lean technique, the waste listed above and the detail workflow have to be provided and presented using a tool for lean analysis, such as value stream mapping (VSM).

The VSM is a tool that can present necessary information and data for lean analysis in a graphic way. The flow-chart-like presentation can easily describe the whole workflow of manufacture. Also, detailed information such as work force, work time and resources used in each step can be noted.

Moreover, such an interface-friendly tool presents all the information in an intuitive way, which can be easily accepted by researchers, managers and engineers.

5.2 Opportunities of optimization in S&C

The lean technique was originally observed in the automotive industry and applied in other sectors. However, few applications were reported in railway industry. It is a challenge to apply lean technique in railway S&C, since the system has some quite different features compared with conventional industries:

- Railway S&C is a large and distributed system. Thousands of S&Cs may be installed along a railway line managed by different operators.
- S&Cs are generally exposed in outdoor environment. They have to suffer from various hard climatic conditions, such as heat, cold, sunshine, wind, snow and ice.
- S&Cs are distributed along different types of railways, such as passenger, freight or mixed lines. They can be used on the conventional, high-speed or heavy-haul lines.
- S&Cs have special moveable components, which cause more failures than other components on the fixed track.
- Maintenance of S&C contains lots of manual work, which have to be performed during train-free period.

According to the above features, the following possible optimization to S&C can be performed from the viewpoint of lean:

1. Choices of lubrication. As one of the failures of S&C is caused by insufficient lubrication, the choices of lubrication should be considered. Lubricants should be selected according the local climatic conditions, since the service temperature range and viscosity largely depend on these factors. Moreover, conventional lubrication work are performed manually, improvement can be made if automatic lubrication technique or lubrication-free S&C can be accepted.
2. Optimization of layout of S&Cs at stations. In order to reduce excessive maintenance work due to unnecessary S&C, the choices regarding the installation of S&C at stations will be discussed in the current project. Evaluation will be performed to decide whether to keep layouts of S&C with redundancy in case of a fault, or to minimize the number of S&C to avoid excessive maintenance.
3. Choices of debris-proof systems. Obstructed turnout occurs due to ice or when ballast particles are thrown out. The obstruction is generally caused during cold weather or for high-speed train movement. In order to avoid or clear such obstruction, appropriate systems can be chosen.
4. Fasteners with great integrity. Conventional fastening systems often consist of a large number of components, which makes the installation work complicated and brings possibilities of component failures. In order to overcome these problems, fasteners with great integrity can be used to simplify the installation and maintenance work.
5. Other maintenance works, such as replacement of S&C, can be reviewed in order to eliminate waste and improve workflow.

5.3 Lean methodology for S&C

As presented in the previous section, railway S&C has special features compared with that of classic industries. The current task focuses on the maintenance of S&C rather than conventional manufacture process. Thus, the lean philosophy will be kept, however, the analysis and the application of lean will be more flexible when considering some special issues.

In this task, the lean methodology for S&C can be generalized as follows:

1. Data collection. The preparing work is to collect as much and detail data as possible, regarding current lubrication techniques, layout of S&C at stations, debris-proof and fastening systems, and also other maintenance works, climatic conditions and failure information.
2. The VSM will be built with the data collected, in order to describe the current state of S&C and their maintenance work.
3. Analysis will be performed on the VSM to find possible optimization opportunities.
4. Detailed solution of improvement will be made and applied by the IM.
5. Periodical inspection and data collection will be made, in order to evaluate the effect of application and make continuous improvement.

The current deliverable focuses on the data collection. Further analysis and application will be performed in Task 2.3.2 (Application of lean and automotive industry techniques to railway S&C).

6. Conclusions

This document contains the data collected for the application of lean and automotive techniques in railway S&C. It aims to provide actual and detailed data covering various aspects of S&C and their maintenance procedures for further use in Task 2.3.2 of the NeTIRail-INFRA project.

This deliverable does not provide an exhaustive collection of data to support lean analysis of S&C. Moreover, new technologies of S&C application and maintenance are still under development. However, this document collects as much data available as possible, from various sources. These data covers the following aspects:

1. Choice of lubricants for S&C with key parameters (service temperature range, form, viscosity, producer, application method, etc.);
2. Layout of S&Cs at stations and their corresponding detailed parameters.
3. Debris-proof techniques and systems to prevent block of S&C due to snow, ice and other debris.
4. Fastening systems with integrity.
5. Detailed procedure of S&C maintenance (work flow, work force, work time, machinery, etc.).
6. Climatic conditions along case study lines.

This deliverable will be used in Task 2.3.2 (Application of lean and automotive industry techniques to railway S&C) of the NeTIRail-INFRA project. Some of the data can be also used in other tasks or studies.

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