The Swiss experience on the wear of railway switches & crossings

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Abstract

Using databases of the Swiss Federal Railways (SBB CFF FFS), statistical analyses are carried out on the expected lifetime of railway switches (points) & crossings and their respective components. The expected lifetimes are attributed to different parameters which influence the speed of degradation or wear, e.g. total train loads (expressed in cumulative tonnages), axle loads, train type, the quality of the foundation or the quality of initial installation. First results confirm long known basic knowledge, e.g. an increase in the average replacement age due to better components and changing maintenance politics.

At the same time unexpected results are found. Examples of this are the not statistically confirmed reduced lifetime of a switch being placed in a curve, or the complete irrelevance of the switch angle on their expected life duration, although a shorter life with larger angles would be expected due to higher dynamic lateral loads. Some explanations for these unexpected results are given and are probably related to both the situation in the field and non technical maintenance politics.

With this knowledge on degradation, a model is composed which is used to forecast maintenance and renewal needs of switches, crossings and their components. To test the model, an old asset database with switches and crossings is used, and the results of the model (proposed replacements including the time of replacement) is compared with the actually carried out works.

Keywords

railway – maintenance – renewal – switches – LCC – management

On the front page: A complex combination of multiple switches & crossings at the marshalling yard of Sibelin (France)

1. Introduction

The devices in the railway superstructure that allow trains to change from one track to another are called switches[1]. The devices that allow trains to cross tracks are called crossings. This changing or crossing of tracks is a necessity to use the railway tracks in the most optimal way and to allow trains to be directed in different directions. At the same time switches and crossings (S&C) are also relatively delicate devices with moving parts, subjected to high, local, repetitive forces and vibrations: e.g. axle loads up to 22.5 tons and train speeds up to 250 km/h in Switzerland. Due to this, the different parts of the S&C will wear and the geometry will deteriorate, up to a certain predefined limit and detected through regular inspections. To avoid any incidents or interruptions of the timetable, maintenance and renewal actions are carried out before this limit is reached and the trains can continue to roll comfortably.

The maintenance and renewal of the SBB railway infrastructure (tracks, overhead lines, signalling, tunnels, bridges, embankments etc.) costs approximately 3 billion Swiss Francs per year[2]. A big part of it is used for maintaining the tracks in a proper condition, including the S&C. To attribute this budget to the track, overhead lines etc. on the complete network, decision support models have been developed to add the maintenance and renewal planner with its task. For plain track these models and their application in computer programs have been finalized [Rivier (1998)]. However, for S&C there still lacks an understanding of the wear and degradation phenomenon and its relationship with parameters that influence this process, e.g. the trains which run over the track.

Therefore, this project puts its focus on understanding the phenomenon of wear and degradation of S&C and its components and relates it to parameters which influence this degradation and wear. To achieve this, multiple SBB databases are combined to find relations between different track parameters and train parameters on one side and the carried out maintenance and renewals on the other side. In the previous STRC article, the first results of the literature study were presented [Zwanenburg (2006-1)]. In this article the first results from the data analysis will follow.

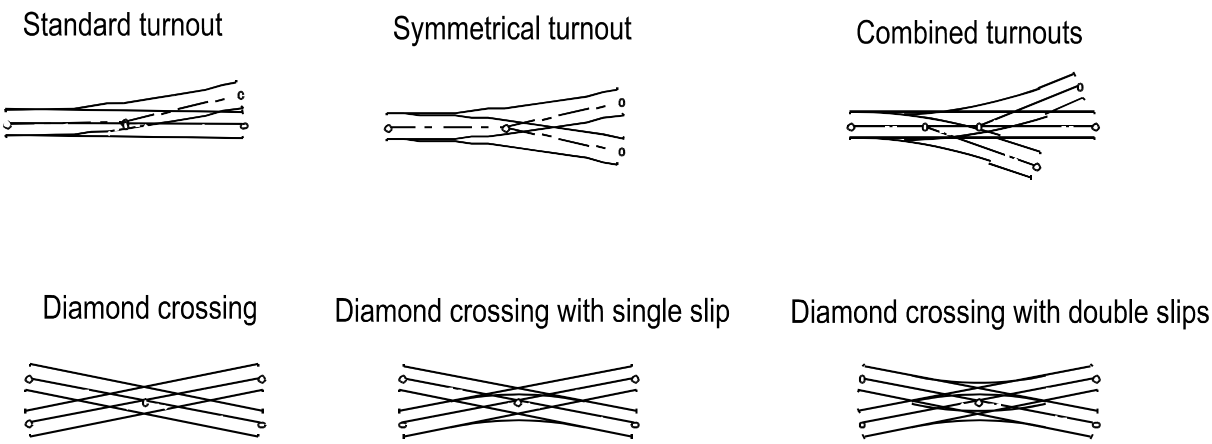
[1] “Switches” is the American-English term. The same device is also more generally known as “turnout” or in the UK as “set of points”.

[2] Figure from 2006

2. Switches & crossings and their components

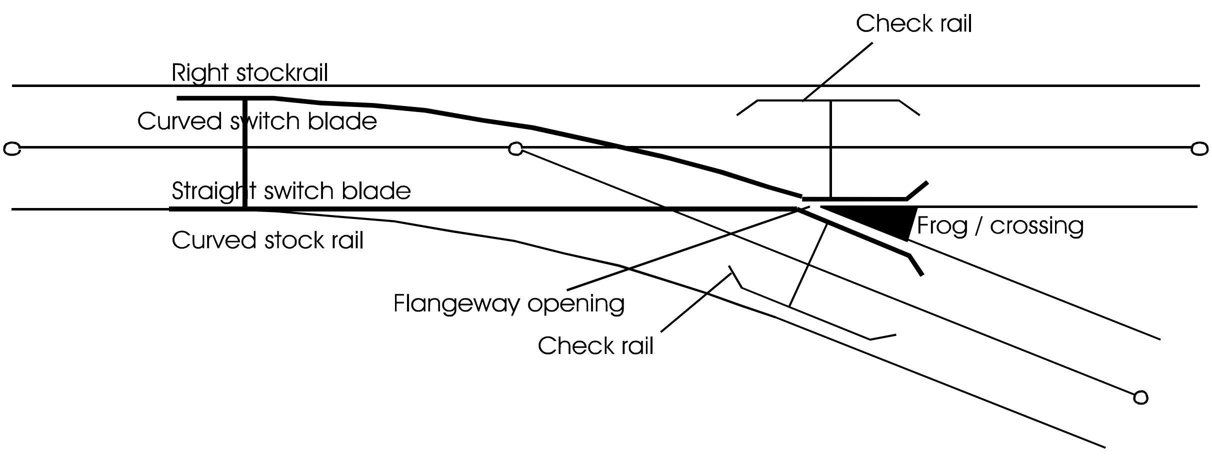
There are different types of switches and crossings (figure 1) and they consist of different components (figure 2).

Figure 1 Different types of switches and crossings



Source: Rivier, R.E. (2004)

Figure 2 Schematized standard turnout and its components



Source: Rivier, R.E. (2000)

Compared with plain track (i.e. straight tracks or curves, only made up of ballast, sleepers and rails, rigidly connected to each other) a switch or crossing contains several special properties.

First of all, it has moving parts, the switch blades, which make it more like a machine than like a type of line infrastructure. Second, it is subjected to high, concentrated, dynamic forces, mainly due to the flangeway opening (cf. figure 2) at the frog which a train wheel has to "jump" and the fact that the curved direction has a small radius without cant[3], which causes high lateral forces. Due to the short (or non-existence of a) transition curve in the switch or crossing, there is also a rapid change in the lateral acceleration, called the jerk. A phenomenon that can be noticed by the train traveller through big sideway movements just before a train enters a station. The third special property is that 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 lead to direct derailment of the first train that will run over it.

These properties lead to special maintenance and renewal necessities which will be described in the next chapter.

[3] in American-English also known as "superelevation"

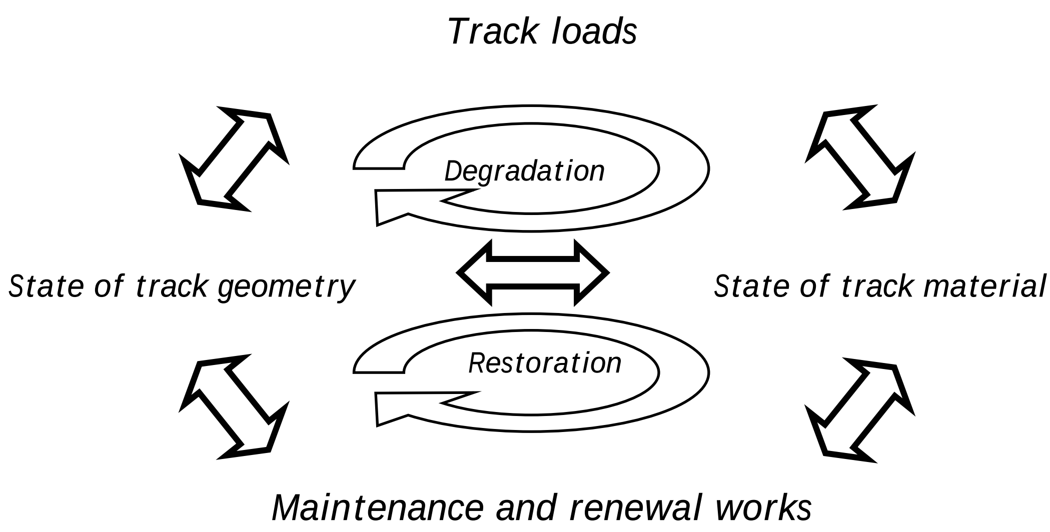
3. Degradation and restoration

3.1 Introduction

Trains running over railway tracks cause degradation of these tracks and its components (rail, rail fastenings, rail pads, sleepers, ballast etc.). The speed of this degradation depends mainly on:

- train properties:
  - axle loads: the higher they are, the more wear the track will show;
  - train speed: the higher it is, the more wear the track will show;
  - total load: the higher it is, the more wear the track will show;
  - train condition: a well maintained TGV train causes less degradation and wear than a train with the same weight but less well maintained;
  - etc.
- track properties:
  - the condition of the support (sub-base);
  - the quality of the materials (e.g. metal hardness, ballast abrasion resistance);
  - the installation quality of a switch or crossing: a properly installed switch will show less wear than a poorly installed one;
  - the track geometry: train tracks in bad geometrical condition will cause “rollercoaster”-behaviour of the train, which results in higher dynamic loads from the train on the track;
  - the state of the track material: bad sleepers or worn rails will provide a unsmooth running path, resulting in vibrations, which as a result cause faster degradation of other track components;
  - etc.

Figure 3 Model for the degradation and restoration of railway track (components)



Source: Rivier, R.E. (2000)

Beside the effect of the train loads on the degradation of the track geometry and the wear of the track material, there is also a relation between track geometry and the state of the material: bad material causes more track geometrical degradation. This relation is also valid the other way: bad track geometry will in the same negative way affect the state of the track material.

To repair the bad track geometry, maintenance and renewal actions like tamping and grinding are carried out. To repair worn track materials, they can be replaced or repaired at site.

The above described relations are presented in figure 3.

3.2 The degradation process

A failure mode analyses of the Dutch rail infrastructure manager Prorail shows that there are 75 different wear and degradation phenomena of the mechanical parts of a switch or crossing[4] [ProRail (2000)]. These can be various geometrical types of degradation like an unintended shift up/down or left/right of the track (figure 4) or wear of the material like burrs (figure 5) or even cracks.

Figure 4 Unintended shift of the track (Flamatt (FR), Switzerland 13 August 2007)

Source: « Le Matin », 14 August 2007

The way this wear or degradation occurs is always different. If a switch or crossing or its components are new, they have an initial quality Q_i. The trains running over the switch or crossing will then cause wear and degradation. The trend line of this wear can have various shapes as shown in figure 6. This shape depends on several parameters as described in §3.1. A higher speed can for example lead to a faster decrease in the quality (figure 7).

[4] Note that this excludes the heating devices (necessary to avoid that the moving parts get frozen during winter time) and actuator (switch motor), which are the cause of a lot of malfunctions.

Figure 5 Example of a burr on the rail that has to be ground off (France, 2005)

Figure 6 Linear, progressive, regressive and instantaneous degradation curves

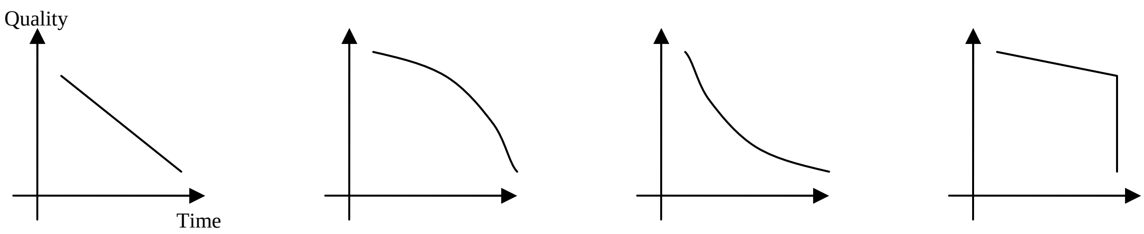
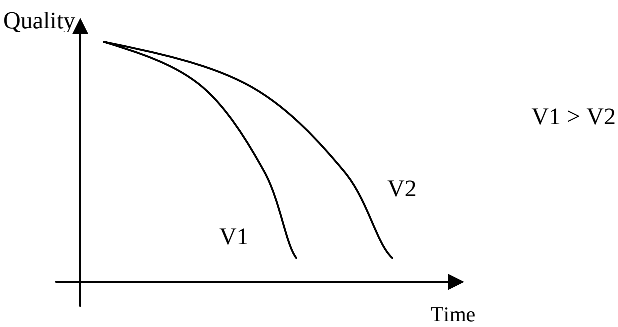


Figure 7 Degradation curve where a higher speed (V1) leads to faster degradation



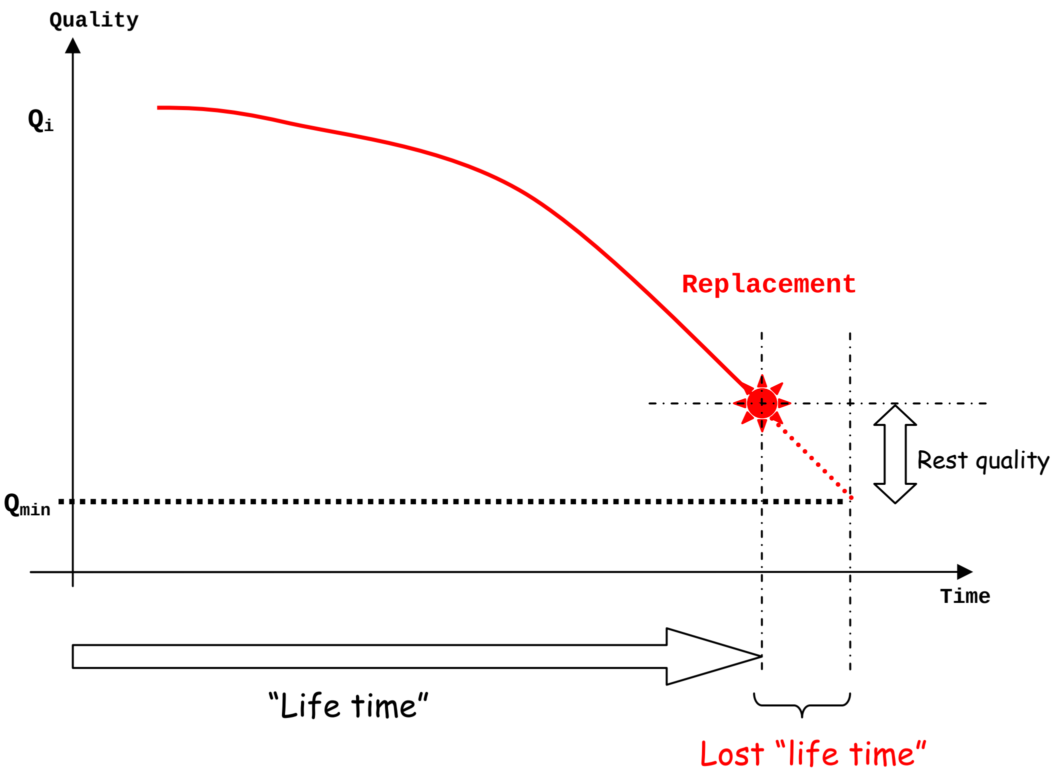
The replacement or maintenance action takes place before the minimum allowable quality limit Q_{min} is reached. If this Q_{min} would be passed a safety issue might occur. In reality already before this Q_{min} is reached, the component or switch is replaced or repaired. This is because of several reasons:

- inspections, mostly on foot, which detect if the Q_{min} is reached, take place once every 4 to 12 weeks. It may detect that the Q_{min} is not reached yet at that moment, but soon after the inspection a component might wear more and pass the limit;
- on a heavily used network like the Swiss railway network, certain works which needs closure of the track, can very often only be carried out in certain periods when trains are rerouted or temporarily halted. It is then not possible to wait until a component or complete switch is completely worn, but it has to be renewed or repaired at the moment the timetable allows a repair;
- the optimization of the use of equipment and personnel makes it necessary that several different works are carried out at the same time sometimes obligating to replace components before they really have to be replaced, but only because personnel or equipment will not be available after that for a while on that certain location;
- statistically derived trend lines are never used to determine the degradation and thus the precise moment maintenance or renewal is necessary.

This early replacement means economically a loss of productivity of the assets, i.e. the switches and crossings and their respective components, since they are replaced before their end of life. Any extension of the life time through a more accurate prediction of the life time might lead to a reduction of the losses caused by the points mentioned above. This loss is graphically explained in figure 8.

When analyzing replacement ages (“Life time” in figure 8), like in this project, it should always be taken into account that it is always replaced before the actual end of life.

Figure 8 Degradation curve with indication of the lost "life time"



3.3 The restoration process

3.3.1 Introduction

The restoration process, as depicted in figure 3, is the improvement of the track geometry or the state of the track components by renewal or maintenance actions. The most interesting part of this process is that principal restoration actions can be achieved by a renewal or a maintenance action. For example, if a piece of metal from the rail head has broken out, this piece of rail can be replaced completely or a small piece of metal can be welded on. Welding a small piece on is cheaper regarding the initial investment, however with a lower guarantee of success and a lower extension of the life of the component. Figure 9 shows a picture of a part of a diamond crossing with slips (cf. figure 1) on which a new squared piece of metal has been welded on.

The principle question regarding maintenance and renewal is when a part is repaired or when it is replaced. The answer to these choices is regarded as the maintenance policy.

Figure 9 Part of a crossing where a rectangular piece of metal is welded on (France, 2005)

3.3.2 (Partial) Renewals

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. Later in this article, an analysis of complete switch renewals related to the use of the track, is presented.

More often only the worn parts are replaced. The switch or crossing components most often replaced are:

- the curved switch blade, but almost always in combination with the right stock rail;
- the straight switch blade, but almost always in combination with the curved stock rail
- the frog/crossing;

- the check rail;
- the rails between the frog and the switch blades;
- the sleepers[5] (the wooden or concrete supports under the switch or crossing; not mentioned in figure 2);
- the ballast (the broken stones supporting the switch or crossing, not mentioned in figure 2).

In this project the replacements of complete switches is analyzed. Also the replacement of switch blades, frogs and check rails will be regarded.

3.3.3 Maintenance

A major part of the restoration of switches and crossings is formed by maintenance action without any replacements, but just by adjustments. Geometrical failures (e.g. cant or shift of the complete switch) can for example be adjusted by relining and tamping the ballast to support the switch or crossings in its new position. E.g. wear of the check rail leads to a bigger distance between this check rail and the running rail, which has a certain maximum to avoid derailment. If this maximum is reached, the check rail can be adjusted closer to the running rail. No replacement or new material is in this case necessary.

In this project the maintenance actions tamping, welding and grinding will be analyzed. [6]

[5] in American-English also known as “ties”

[6] parts of the text in this chapter were previously published in [Zwanenburg (2006-1)]

4. Analysis of complete switch or crossing renewal ages

Rules of the thumb inside the railway industry regarding maintenance and renewal needs for switches and crossings (S&C) are tested with the SBB databases. They are:

1. S&C incorporated in more important track types (more and/or faster trains and/or heavier axle loads) will show higher deterioration rates than S&C in tracks with a lower density of trains or lighter trains.

2. Curved S&C are exposed to higher dynamic forces and have therefore a shorter lifetime than S&C on plain track.

3. S&C with a smaller angle show less wear (i.e. a 1:15 switch will show less wear than a 1:9 switch).

The conclusion is that only for the above mentioned rule 1 (train loads) a significant relationship with the replacement ages can be found, although the standard deviations of the results are high.

For the second rule, the surprising result was obtained, that the average replacement age of a curved switch was exactly the same as that of a normal standard turnout.

For the third rule no relationship at all could be found. However this last result was quite easy to explain: 1:9 switches (with a big angle) are normally part of stations or connect sidings to main tracks. The speed on the curved direction is low, or the switch is even used seldom in the curved direction. This on the contrary to 1:15 switches which are normally integrated in plain track and know a heavy load and normal speed in both directions.

A general trend was found that the average replacement age increased slightly during the evaluation period (1997-2005). This is mainly due to the introduction of better materials and maintenance procedures and will continue through introduction of even better materials.

Extra tests are necessary to see if there exist correlations with other factors, because only with track loads, the relationship is rather weak. The most important result is that there apparently are other factors also important which might reduce the standard deviation if they are included in the evaluation and for which the switches and crossings should be analyzed more in-depth. These are parameters like the subsoil condition, the quality of initial placement or the maximum axle load. These things are taken into account during the next steps of this study.[7]

[7] parts of the text in this chapter were previously published in [Zwanenburg (2006-2)]

5. The next steps of this study

The next step of this study consists of combining maintenance and renewal needs of the complete switch or crossings and all the components with their loads, combined with parameters that influence the degradation in another way, like the train and track parameters described in paragraph 3.1 depending on their availability. Operations research will be used to derive the model and relationships between the different parameters.

The model can be tested by taking the derived model and apply it on a database of switches and crossings of 1997. By then applying the real train loads from the period between 1997 and 2007, the current situation should be the result including all the maintenance and renewal that has been carried out in the period 1997-2007. The rate of difference with the reality should indicate the reliability of the model.

The influence of the maintenance policy on the derived model can be tested by introducing maintenance and renewal figures of foreign networks with different maintenance policies. Contacts have been established for that.

After that test cases can be used to:

- determine the maintenance and renewal needs for the next 10 years,
- determine switches and crossings (components) maintenance and renewal optimization (especially by applying a different maintenance and renewal policy and comparing the different costs),
- be used as a test to see if a change of lay out of switches and crossings, if possible, could change the maintenance and renewal needs in the long term.

Already the results are thought as an input for another PhD study on the optimisation of the RAMS[8] design philosophies of large station entrances, which normally include a high number of switches and crossings.

This is all being done with as main reason to better attribute the maintenance and renewal budget.

[8] Reliavility, Availability, Maintainability and Safety

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