

# Comparison and ranking of Swiss railway incident data from 2000–2009

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## Abstract

Supervision of the safety performance in public transport is one of the main tasks of the Federal Office of Transport (FOT) in Switzerland. Recently a three level system of safety indicators has been defined to cover all means of Swiss public transport. The safety indicators are fed by the FOT incident database since the year 2000 and it is covering all transport companies having a license to operate in Switzerland. In cooperation with the Institute for Traffic Safety and Automation Engineering (iVA) at Technical University Braunschweig, Germany, FOT is developing a suitable methodology for the definition and evaluation of the safety targets in Swiss public transport. The methodology is applied for evaluation of safety indicators on a country level and for single transport companies, taking into account the statistical significance of the rare events incident data, which very often cannot be interpreted by conventional methods of data analyses based on simple averaging.

*Keywords: statistical analysis, safety, risk, scale, ranking, railway, public transport, Switzerland.*

## 1 System of safety indicators, motivation and overview

Long term railway accident analyses on an aggregated level are being carried out on a regular basis [1, 2]. Due to lack of in-depth data, incidents are usually not categorised. With railway incident data from Switzerland a categorisation of data was possible and is described in this paper. According to the Safety Concept of the Federal Office of Transport [3] the safety in the Swiss public transport must be kept on the present level, despite the rise of transportation volume. For this



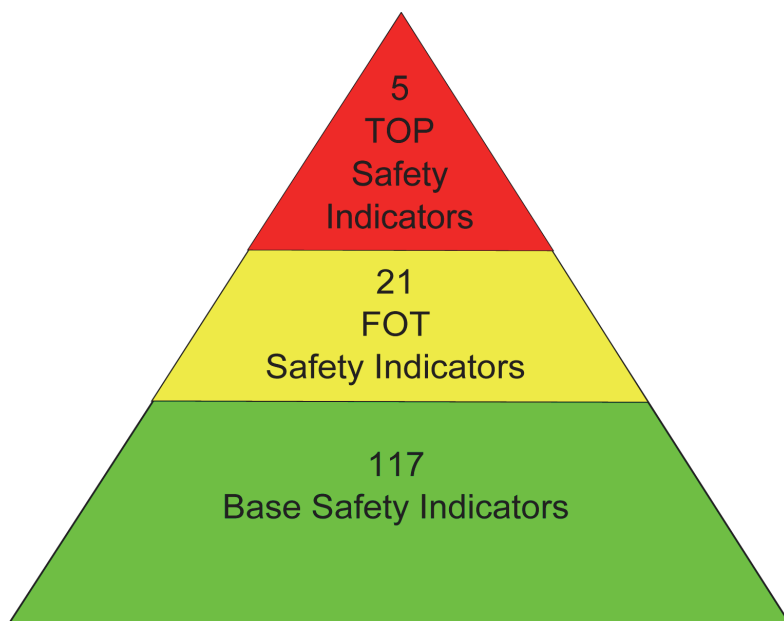


Figure 1: System of safety indicators.

purpose a system of safety indicators to classify incidents in public transport has been developed [4]. The system consists of three levels of aggregation as depicted in figure 1.

The full set of 117 base safety indicators is used to perform a classification at a very detailed level. The set of 21 FOT safety indicators at the second level comprises the 117 indicators, represents the first abstraction level and is covering more than 90% of the incident's risk. The highest level of aggregation, the TOP safety indicators can be seen as a "management summary" and are used for internal communication purposes of the Swiss department of transport. The main design goal of this system of indicators is the supervision of the safety performance with the possibility of identification of causes and responsible transport companies.

In this paper the 21 FOT safety indicators of level 2 are used to define and evaluate safety targets for Switzerland and for Swiss public transport companies.

The new proposed methodology provides a transparent safety monitoring system that can be used by the FOT to measure the effectiveness of safety measures and to provide starting points for company safety audits.

An incident database, described in the next section, provides the necessary input to perform the definition of safety targets and the evaluation of the safety performance on country and company level, both described in the methodology section. A summary of the paper can be found in the result section at the end of this paper, some considerations about things to do are discussed in the final outlook section.

## 2 Incident database analysis

The incident database of the FOT was started in the year 2000 and records incidents of all modes of public transport (rail, tram, bus, ship, cableways). From the more than 14000 incidents most records are from the railway domain. The procedure of recording in that domain is well established and therefore approx. 8000 incidents were recorded from 2000 to 2009. These incidents are used as an input for the following statistical analyses.

### 2.1 Statistical analysis

Consistency checks were performed to evaluate the usability of the incidents stored in the database. Figure 2 shows that expected patterns in the dataset could be

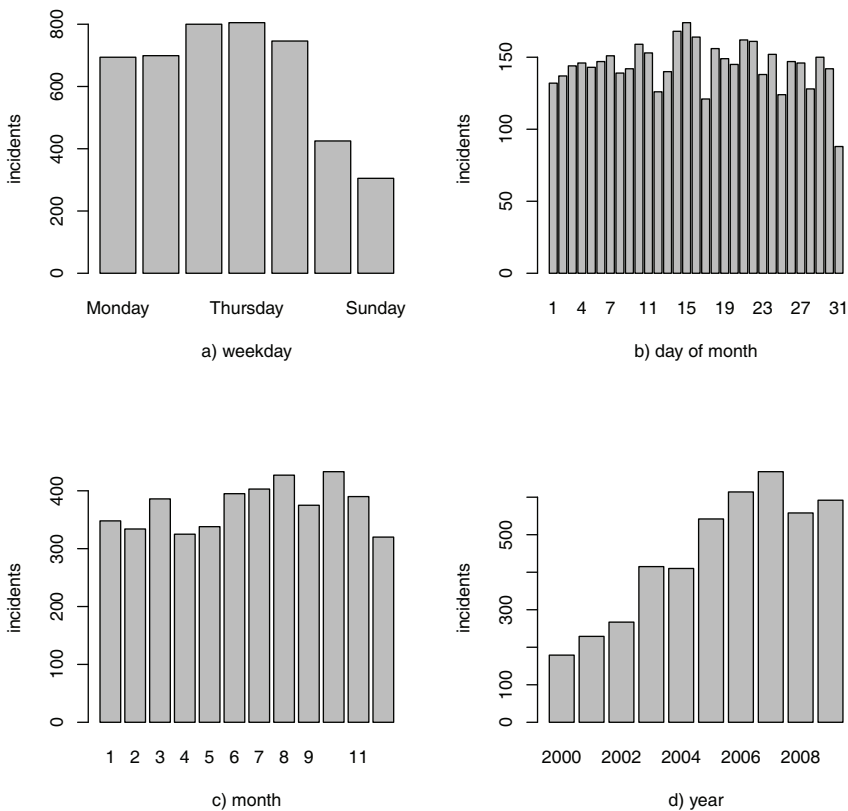


Figure 2: Statistical analyses of incidents.

is less frequent on these days (a). Incidents are evenly distributed on days per month with fewer incidents on the 31st (b). Equally, incidents per month can be seen in (c). The only deviation of expectation is found in (d). The impression that the number of incidents increased over time needs an explanation. Two reasons could be identified. First the system of recording the incidents was modified in 2005 which lead to an increase of (recorded) incidents. The most significant increase is observed in incidents without personal injuries and incidents with light injuries. Secondly the system of recording the incidents needed some time to be established with the railway companies; therefore the data of the early two to three years is somewhat incomplete.

In order to eliminate the influence of the increase of number of incidents during the time period a number of rules for definition of relevant incident have been developed.

The numbers of incidents which caused a FWI for selected indicators are depicted in figure 3. It can be seen that indicators which involve collisions are well maintained since the beginning of data recording (EA11 and EB11).

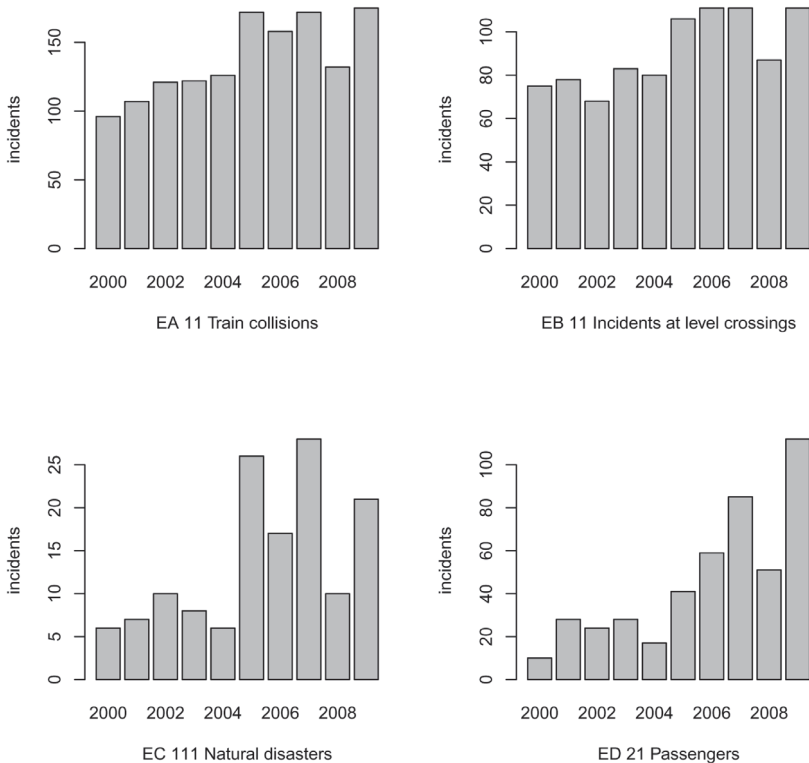


Figure 3: Numbers of (FWI)-incidents of selected indicators.

Natural disasters are of a very random nature (EC 111). While the indicator for passengers (ED21) suggests, that the risk increased, the “growing” numbers were caused by changes in the data collection process. From 2005 it is mandatory to record incidents with light injuries, additionally railway companies are educated to improve their recording procedures.

## 2.2 Distribution identification

Each incident was assigned up to four of the 21 FOT safety indicators (table 1 and table 2), explaining what happened (EA indicators), where did it happen (EB indicator), why did the incident happen (EC indicators) and who was affected/harmed (ED indicators). For each of the 21 BAV safety indicators the mean time between failure rates (MTBF) were calculated and the distribution of the events identified (Figure 4). Furthermore a distinction was made between the overall number of incidents and the corresponding number of fatalities and weighted injuries (FWI) whereby

$$FWI = fatalities + 0.1 \cdot serious\ injuries + 0.01 \cdot light\ injuries \quad (1)$$

Table 1: Safety Targets: Number of incidents per million train kilometres.

Safety indicator	MIN	AVG	MAX
EA 11 Train collisions	0.289	0.312	0.336
EA 12 Shunting collisions	0.199	0.218	0.238
EA 21 Train derailments	0.111	0.125	0.141
EA 22 Shunting derailments	0.548	0.580	0.612
EA 31 Train at danger	0.305	0.329	0.353
EA 411 Accident with human being	0.196	0.215	0.234
EA 421 Accident at work	0.043	0.052	0.062
EA 512 Vehicle fire	0.045	0.055	0.065
EA 52 Disturbances	0.045	0.055	0.065
EB 11 Incidents at level crossings	0.444	0.473	0.502
EC 111 Natural disasters	0.067	0.078	0.090
EC 21 Technical defect vehicle	0.149	0.166	0.183
EC 22 Technical defect infrastructure	0.085	0.098	0.111
EC 311 Signal passed at danger	0.235	0.255	0.277
EC 313 Spurious action shunting	0.213	0.232	0.253
EC 316 Spurious action work on track	0.297	0.320	0.344
EC 331 Spurious action presence in structure gauge	0.077	0.089	0.101
EC 342 Sabotage / Vandalism	0.036	0.044	0.053

Table 2: Safety Targets: Incident consequence (FWI) per million train kilometres.

Safety indicator	MIN	AVG	MAX
EA 11 Train collisions	0.086	0.096	0.11
EA 12 Shunting collisions	0.0066	0.0079	0.0094
EA 21 Train derailments	0.0008	0.0019	0.0032
EA 22 Shunting derailments	0.00069	0.0011	0.0016
EA 31 Train at danger	0.00053	0.0011	0.0017
EA 411 Accident with human being	0.040	0.044	0.048
EA 421 Accident at work	0.012	0.015	0.018
EA 512 Vehicle fire	0.00005	0.00010	0.00015
EA 52 Disturbances	0.00067	0.0011	0.0016
EB 11 Incidents at level crossings	0.053	0.059	0.066
EC 111 Natural disasters	0.00003	0.00010	0.00020
EC 21 Technical defect vehicle	0.0003	0.0004	0.0005
EC 22 Technical defect infrastructure	0.00005	0.00018	0.00037
EC 311 Signal passed at danger	0.0020	0.0033	0.0049
EC 313 Spurious action shunting	0.0034	0.0048	0.0064
EC 316 Spurious action work on track	0.0075	0.0091	0.0109
EC 331 Spurious action presence in structure gauge	0.039	0.045	0.052
EC 342 Sabotage / Vandalism	0.00018	0.00034	0.00055
ED 21 Passengers (all)	0.040	0.043	0.047
ED 21a Passengers (without personal fault)	0.009	0.011	0.014
ED 22 Staff	0.023	0.026	0.030
ED 25 Third persons (all)	0.14	0.15	0.16
ED 25a Third persons (without personal fault)	0.0017	0.0023	0.0031

The years 2000 and 2001 were not taken into account for this calculation, as missing incidents would suggest a smaller risk of an incident to happen. To make these MTBF rates more comparable they were put in to relation to train kilometres. The details of the methodology are described in the next section.

### 3 Methodology

#### 3.1 Safety targets and statistical significance

About 4600 relevant incidents from the years 2002 to 2009 could be used for the calculations of Swiss safety targets. Despite of a relatively high number of incidents some of the safety indicators only show a very low count of

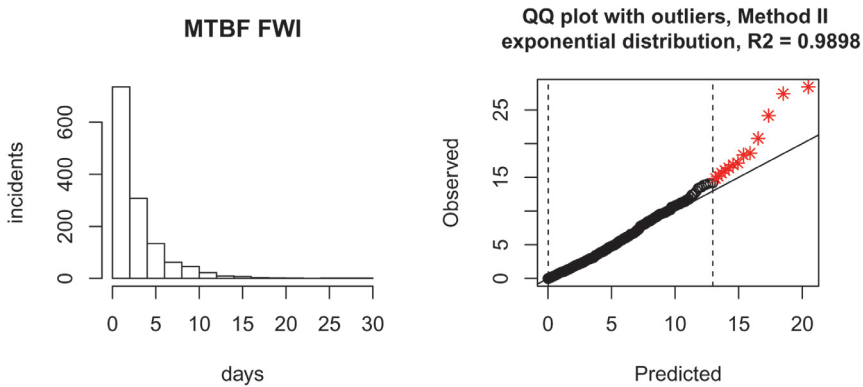


Figure 4: MTBF rates of incidents with FWI and test for exponential distribution.

incidents (e.g. EC111 natural disasters). If data is treated on a company level this problem is even more present. To overcome the difficulties of small numbers, significance levels were calculated for every safety indicator according to its (negative exponential) distribution and its MTBF, thus resulting not in a single value for a safety indicator, but in a from-to range (equation 2) [5]. With these ranges the safety targets for all 21 safety indicators for Switzerland were calculated from the incidents of 2002 to 2009.

For each indicator annual frequencies (number of incidents/year) and consequences (number of FWI/year) as well as their scaled values by millions of train kilometres are computed (see example of incidents/mio. train kilometres in table 1 and FWI/mio. train kilometres in table 2). The methodology differentiates in case of passengers (ED21) and third persons (ED25) the consequences with and without personal fault. These safety targets are taken as a reference for assessment on country and company level described in the next section.

$$\frac{2n\bar{x}}{\chi_{2n,1-\alpha}^2} \leq \frac{1}{\lambda} \leq \frac{2n\bar{x}}{\chi_{2n,\alpha}^2} \quad (2)$$

$\frac{1}{\lambda}$  : Mean Time Between Failures (MTBF)

$\alpha$  : Level of confidence (here 0,05)

$n$  : Number of measurements i.e. degrees of freedom of  $\chi^2$  distribution

$\chi^2$  : Value of the  $\chi^2$  distribution with n degrees of freedom

$\bar{x}$  : Estimated mean value

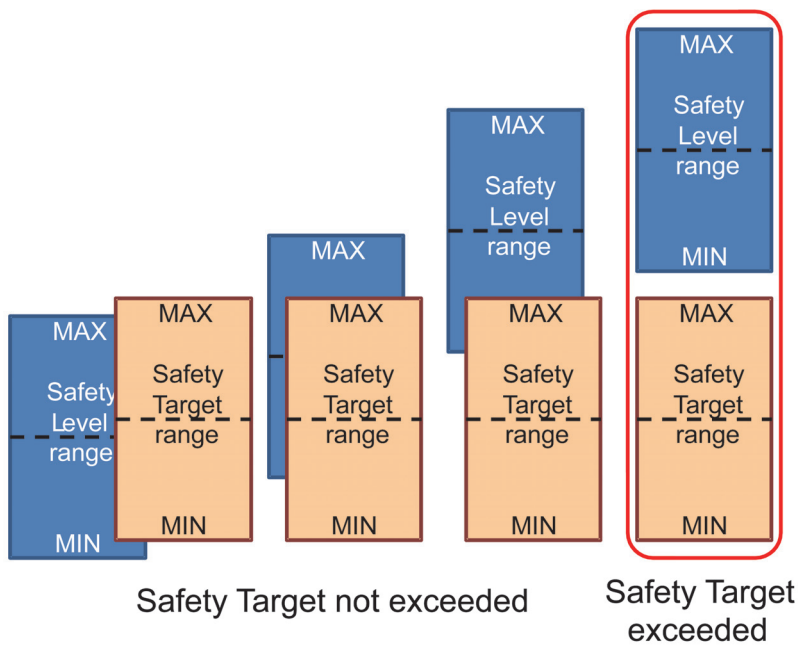


Figure 5: Comparison of safety targets.

### 3.2 Safety level of the country

Evaluation of the safety performance on the country level is carried out by comparison of the safety targets with the indicator value corresponding to a particular year. A deterioration of the safety performance will be identified in the case when the low limit of the indicator's safety range is higher than the upper limit of the target's safety range. An example of the evaluation is shown on figure 5.

Evaluating the incident data from the year 2010 only three indicators refer to a deterioration of the safety performance (EA 411, EB 11, EC 311). In all these cases the exceeding of the target's safety ranges concerns the frequency but not consequences. This is an indication, that here the most probable reason for the deterioration is the improvement of incident reporting's discipline.

### 3.3 Safety level of railway companies

Each incident of the dataset is tagged with a "responsible" company; therefore it is possible to divide the whole dataset in company based datasets (currently 48). For each of the 48 companies train kilometre data (accumulative train trip length) for the years 2006 to 2009 was available for standardisation. To get a suitable number of incidents per company all incidents from the four years were added up. The same procedure of calculating ranges of significance was applied (see 3.2).



Due to the small number of incidents per company the above mentioned ranges are bigger than on a country level. With the ranges on the Swiss country level and the ranges for each company a scale was designed and applied, which is described in the next section.

### 3.4 Ranking of railway companies

The ranges for each of the 21 safety indicators for the country level calculated from the years 2002 to 2009 were taken as a reference (see 3.2). The ranges of the 21 safety indicators for each of the 48 companies calculated from 2006 to 2009 were compared against the country reference. For each comparison a value from 1 (safety level is within range) to X (safety level lies X times higher than allowed) was calculated (figure 5), for the absolute number of accidents, as well as for the FWIs. The values are added up and can be used to compare the safety levels of companies (see ranking in figure 6).

## 4 Results

With the proposed methodology it is possible to generate safety targets on a country level that still offer a detailed insight into the causes of the incidents. As the same calculations are applied to company data it is easy to rate the companies safety performance and to compare companies to each other. The methodology will be used by the FOT and will be the base for a tool to automate the calculation processes.

The first results show, that the evaluation method can be used for transport companies with annual performance higher than 2.5 million train kilometres (about 1% of Swiss railway transport volume). This concerns 12 transport companies. Other 16 companies can be evaluated only partially and the remaining companies (20) cannot be evaluated at all (up to rank 29, see figure 6) due to statistically insignificant incident data. In these companies the audits and inspections will be the main reference in the supervision of the safety performance.

## 5 Outlook

The method is currently applied to transportation companies offering public transport services and goods transportation companies. Infrastructure providers do not generate train kilometres as a statistic and could not yet be integrated into the comparison. In a next step an appropriate standardisation will be applied to incorporate all types of transport companies. The evaluation method of comparing safety targets will be improved by a more sophisticated procedure and therefore the presented numbers should be seen as preliminary results.



Ranking	Railway Company	Risk Number	Nr.of eval. Indicators	Nr. of eval. Indicators >1	Tendency
1	RC1	5	8	8	-0,971
2	RC2	2	2	1	2
3	RC3	2	8	3	-0,6
4	RC4	1,952	21	10	-0,333
5	RC5	1,5	12	5	0,244
6	RC6	1,4	5	1	-1
7	RC7	1,333	9	3	-0,6
8	RC8	1,25	20	4	0,055
9	RC9	1,222	9	2	0,4
10	RC10	1,167	6	1	-0,667
11	RC11	1,167	18	3	-0,055
12	RC12	1,083	12	1	0
13	RC13	1,048	21	1	0,048
14	RC14	1	1	0	0
15	RC15	1	1	0	0
16	RC16	1	1	0	0
17	RC17	1	2	0	0
18	RC18	1	2	0	0
19	RC19	1	5	0	0
20	RC20	1	6	0	0
21	RC21	1	7	0	0
22	RC22	1	9	0	0
23	RC23	1	12	0	0
24	RC24	1	13	0	0
25	RC25	1	14	0	0
26	RC26	1	15	0	0
27	RC27	1	20	0	0
28	RC28	1	20	0	0
29	RC29	0	0	0	0
30	RC30	0	0	0	0
31	RC31	0	0	0	0
32	RC32	0	0	0	0
33	RC33	0	0	0	0
34	RC34	0	0	0	0
35	RC35	0	0	0	0
36	RC36	0	0	0	0
37	RC37	0	0	0	0
38	RC38	0	0	0	0
39	RC39	0	0	0	0
40	RC40	0	0	0	0
41	RC41	0	0	0	0
42	RC42	0	0	0	0
43	RC43	0	0	0	0
44	RC44	0	0	0	0
45	RC45	0	0	0	0
46	RC46	0	0	0	0
47	RC47	0	0	0	0
48	RC48	0	0	0	0

Figure 6: Company comparison.

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