

Safety evaluations of level crossings

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SUMMARY

Over the last few years in Finland the number of level crossings has been reduced by around 150 yearly. A recently finalised safety evaluation tool has revealed that removing 5% of level crossings included in the tool has cut the expected number of accidents by less than 3%. This Internet-based, username- and password-protected tool is used by the Finnish Transport Agency and the Finnish Transport Safety Agency, and aims primarily to help in the selection of treated level crossings and evaluate the safety effects of different measures.

Using the tool one can (i) estimate the current safety situation of nearly all level crossings on the state rail network and (ii) evaluate the safety effects of improvements at any of those level crossings. With information on average or known costs of level crossing (LC) improvements it is even possible to estimate the cost-effectiveness of an improvement or combination of improvements.

The estimate of current safety is calculated using an empirical Bayesian method combining information from an accident prediction model with accident numbers for the past 12 years. The safety effects of LC improvements are evaluated using the safety estimates and crash modification functions (CMF), also known as impact coefficients. The impact CMFs are selected based on the most reliable studies carried out internationally in respective conditions.

INTRODUCTION

The distribution of the number of expected accidents between level crossings is far from uniform. Without a proper evaluation tool it has been impossible to know which level crossing should be removed or improved for safety reasons. A new estimate carried out with the recently introduced TarvaLC evaluation tool suggests that 10% of the most risky level crossings in Finland produce more than half of all level crossing accidents. Similar tools have been produced for road safety evaluation in Finland and Lithuania.

The uneven distribution of accidents among level crossings calls for good information on the risks at different locations. The earlier method for prioritising level crossing measures turned out to overemphasize well-designed and equipped level crossings with a relatively high number of road vehicles.

This paper introduces the principles of the evaluation tool and its practical use of it, together with some results.

NOTATION

Current safety Expected number of accidents if no changes are made to the level crossing.

CMF Crash Modification Function (CMF) — describes the safety effect of a measure. Terms like impact coefficient and Crash Modification Factor have also been used.

PRINCIPLES OF THE SAFETY EVALUATIONS

The number of accidents at level crossings is often so small that evaluation of risks based purely on these is unreliable. This is definitely the case in Finland, where the average number of accidents per level crossing is around 0.1 in 10 years, but at one level crossing the respective number is almost 5 (Figure 1).

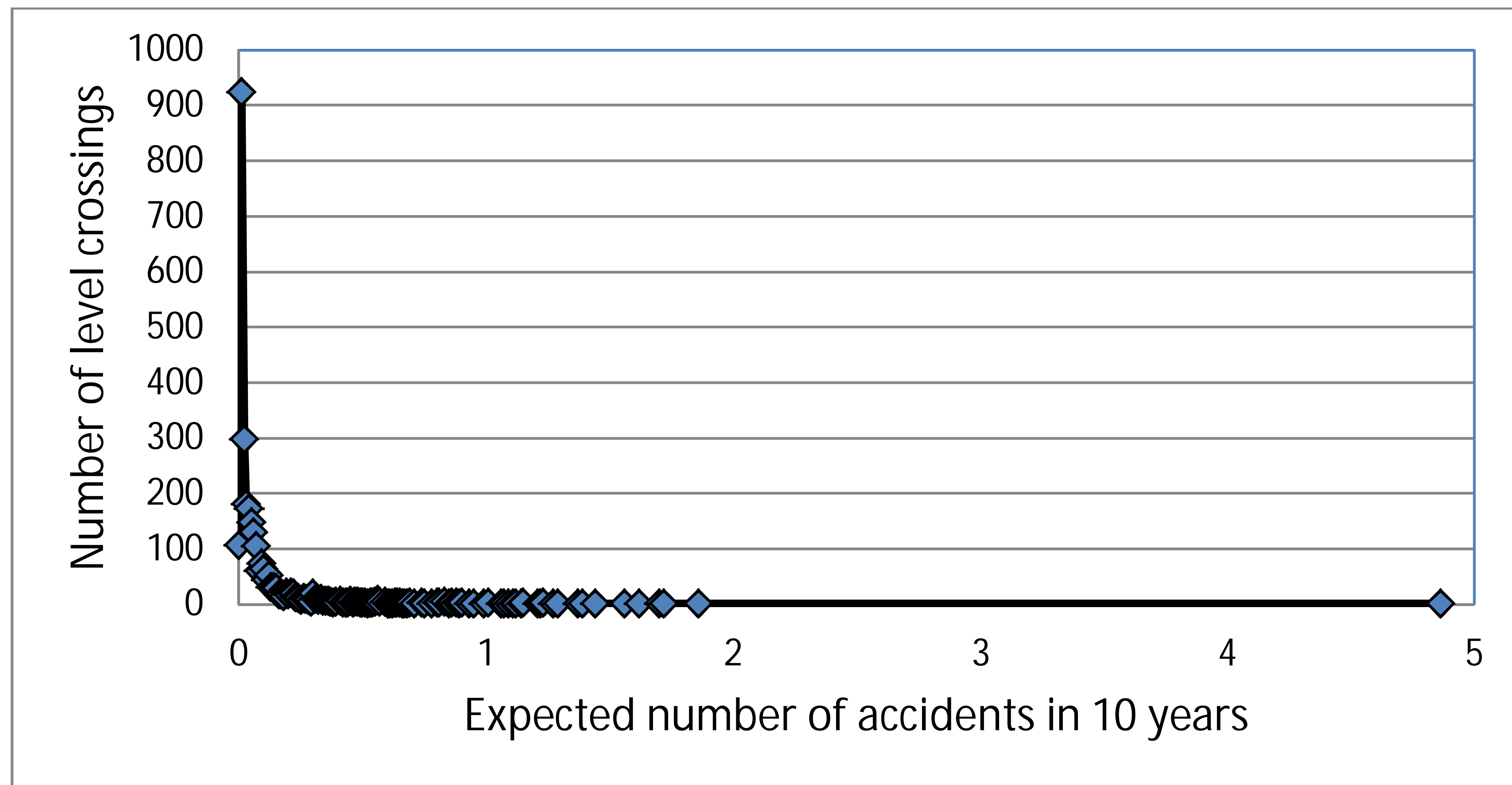


Figure 1: Number of level crossings by their expected accident number

Estimating the current safety of level crossings

The expected accident numbers in Figure 1 have been calculated using an empirical Bayesian method that combines information from an accident prediction model with accident numbers for the last 12 years (Figure 2). The accident models were built based on registers of rail characteristics, recorded accidents and data collected in special inventories [1]. One example of an accident prediction model is given in Appendix 1.

If there are major changes in the number of road or rail vehicles passing a level crossing, or the conditions have otherwise recently changed, this can be taken into account when estimating the expected number of accidents if no improvements are implemented (Figure 2).

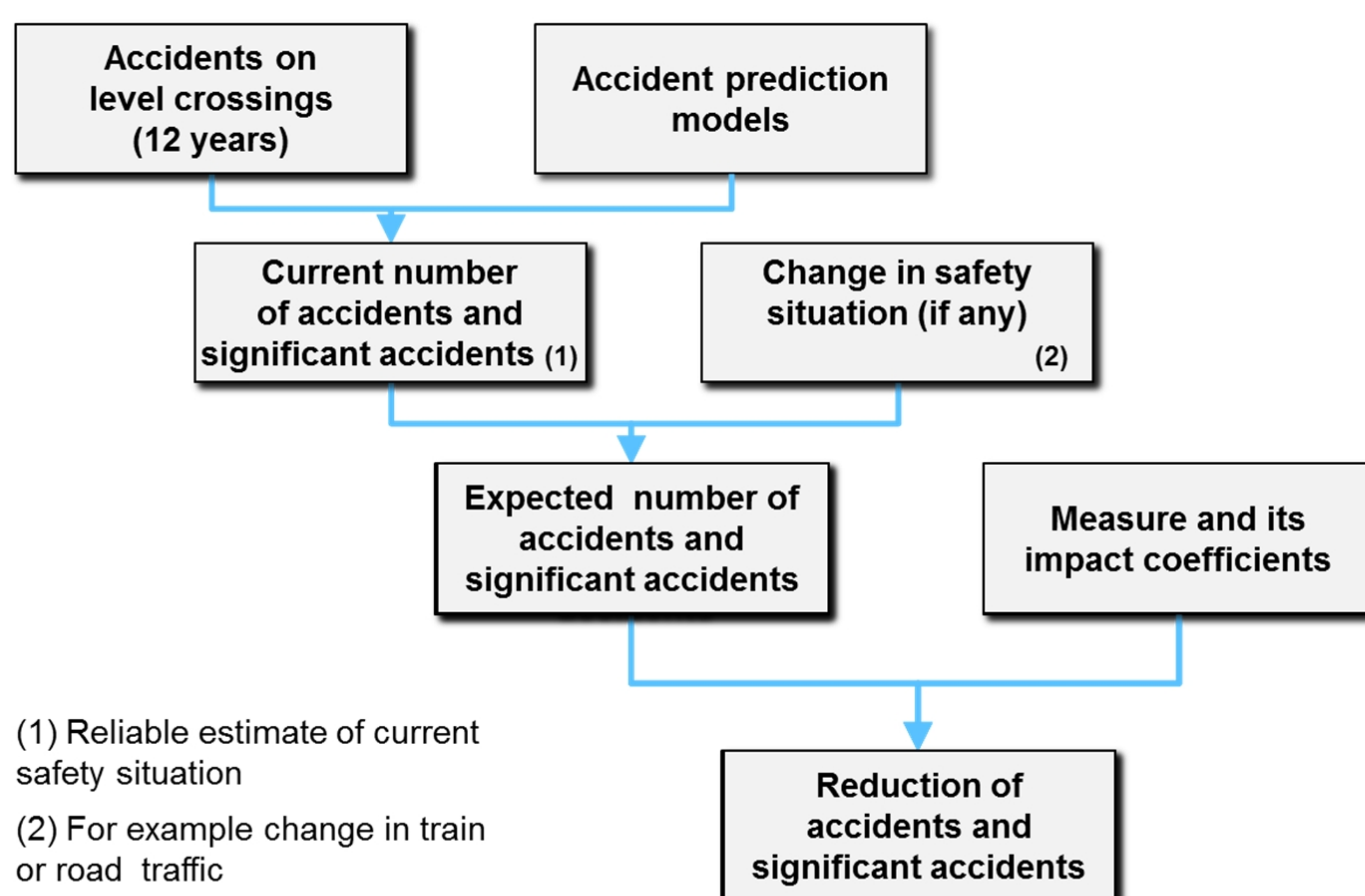


Figure 2: Evaluation principles of the TarvaLC tool.

The estimated numbers of accidents at level crossings can be used when selecting the sites to be treated. Figure 3 shows that removing 10% of the evaluated level crossings with the highest expected number of accidents (risk group 1) could prevent more than 140 accidents in 10 years. However, removing the respective number of level crossings in risk group 10 would only prevent around one accident in 10 years.

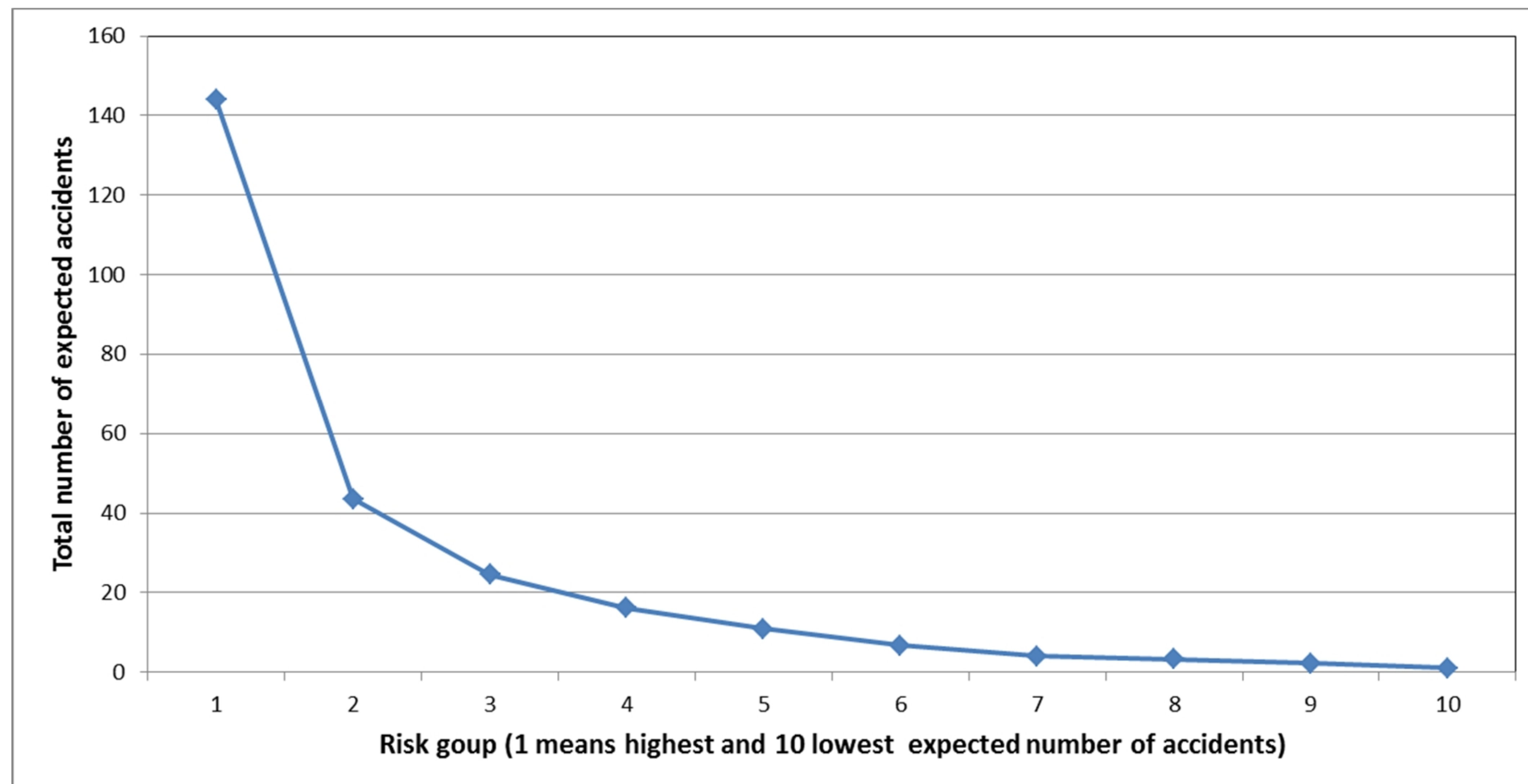


Figure 3: Distribution of expected number of accidents in 10 years between 10 risk groups. Each risk group includes about 10% of all evaluated level crossings; thus group 1 has 10% of LCs with the highest expected number of accidents, etc.

Evaluating the safety effects of improvements

The safety effects of LC improvements are evaluated using the expected number of accidents without measures and CMFs (Figure 2, Formula 1).

$$\text{Expected accidents} = \text{Target accidents} * \text{CMF} \quad (1).$$

The CMFs are selected based on the most reliable studies carried out internationally in respective conditions, such as that by Elvik et al. [2]. It is important to recognise that safety benefits are calculated as a product of two numbers. Even if there is lots of uncertainty in the proposed CMFs, it seems that due to the huge variation in estimated number of accidents (see Figure 1), reliable estimation of target accidents is very important as well — arguably even more so than the CMFs, because huge estimation errors may result if accident history is the sole source of current safety evaluation.

Respective evaluation tools have been produced also for road safety evaluations in both Finland and Lithuania. They estimate numbers of injury accidents and fatalities and any changes in these due to road improvements [3]. Due to the small numbers of accidents, for level crossings (TarvalC) only the number of accidents and significant accidents and their changes due to improvements are estimated.

THE TARVALC EVALUATION TOOL IN PRACTICE

The evaluation tool is used on the Internet by the Finnish Transport Agency and the Finnish Transport Safety Agency, and is username and password protected. The evaluations can be done on any modern computer with an Internet connection and a reasonably new version of Adobe Flash Player.

The expected number of accidents can be estimated simply by defining which level crossing is to be included in the analysis.

Calculation of the safety effects of improvements is done by: (1) selecting a measure and (2) selecting at which level crossing(s) the measure will be implemented. There is also an option to input the implementation cost; if this is not done, default costs are used when defining the cost-effectiveness of measures. One can

also define several measures for a level crossing – the program takes care of the overlapping measures to avoid double counting. There are 27 pre-defined measures (see Appendix 2), but one can also define one's own if there is something missing.

EVALUATION RESULTS

TarvaLC enables the user to (i) estimate the current safety of nearly all level crossings on the state rail network and (ii) evaluate the safety effects of improvements at any of those level crossings. With the help of average or known costs of LC improvements, the user can even estimate the cost-effectiveness of an improvement or combination of improvements.

As an example, Figure 4 shows a comparison of the expected number of accidents at all evaluated level crossings with that at recently removed level crossings over a period of about 1 year. To be able to prevent as many accidents as possible, one should target level crossings having the highest numbers of expected accidents (lowest possible risk group number). However, removed level crossings tend to be mostly low risk.

During the last few years the amount of level crossings has been reduced by around 150 per year. Analysis of recently removed level crossings revealed that by removing 5% of the level crossings included in the evaluation tool, the expected number of accidents fell by less than 3%. This suggests that removal of level crossings is not done (purely) based on expected high accident numbers.

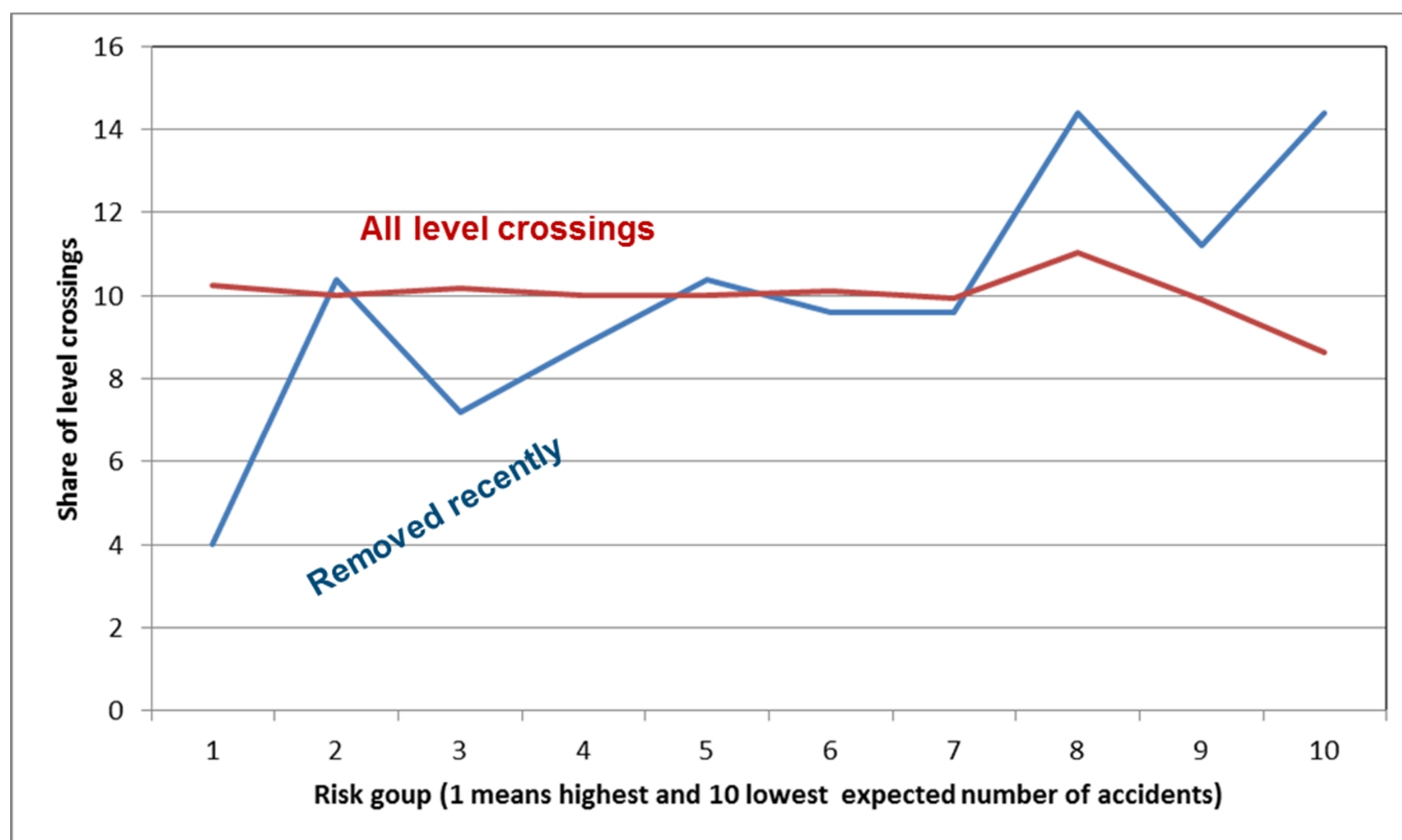


Figure 4: Distribution between 10 risk groups of all level crossings and those removed recently.

CONCLUSIONS

Proper evaluation tools are needed for safety evaluations in order to (1) select level crossings to be removed or improved based on expected numbers of accidents with no measures, (2) evaluate reliably the effects of level crossing improvements, and (3) enhance the cost-effectiveness of safety improvements at level crossings.

Knowledge of the safety effects of different measures is accumulated most effectively if safety research is carried out scientifically and same definitions are used in different countries. Even evaluation tools should be science-based, easy to use and understand, and still simple enough to be updated yearly. Using internationally the same (kind of) evaluation tools would enhance international co-operation and knowledge exchange.

The results from Finland suggest that removal of level crossings is not done (purely) based on expected high accident numbers. To some extent this can be motivated. However, huge differences in expected level crossing accident numbers call for prompt action at high-risk level crossings. Even the effects of improvements or combinations of them can be easily and reliably evaluated using appropriate tools to enhance cost-effectiveness of LC safety improvements.

REFERENCES

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2. Elvik R Høye A Vaa T Sørensen M. The Handbook of Road Safety Measures, second ed. Emerald publishing, Bingley 2009.
3. Peltola H Rajamäki R Luoma J. Tools needed for enhancing transferability of cost-effective road safety measures. Transport Research Arena 2012. Procedia - Social and Behavioral Sciences of Elsevier p. 1234-1243. <http://dx.doi.org/10.1016/j.sbspro.2012.06.1099>, Cited 27.8.2012.

APPENDIX 1/1: EXAMPLE OF AN ACCIDENT PREDICTION MODEL

Number of level crossings in modelling by included variables:

		Number	Share
Safety devices	Light&soun	36	1,3%
	Other	584	20,5%
	No	2227	78,2%
	Total	2847	100,0%
AADT (road vehicles/day)	>100	461	16,2%
	10-100	1041	36,6%
	<10	1345	47,2%
	Total	2847	100,0%
Speed limit on road	80 km/h	2207	77,5%
	< 80 km/h	640	22,5%
	Total	2847	100,0%
Speed limit on railw ay	>=110 km/h	903	31,7%
	<=100 km/h	1944	68,3%
	Total	2847	100,0%
Share of the shortes 8 m sight distance from required (after bush removal)	<40 %	638	22,4%
	>=40 %	2209	77,6%
	Total	2847	100,0%
Road pavement	Gravel	2160	75,9%
	Paved	687	24,1%
	Total	2847	100,0%

Prediction model for level crossing accidents - statistically significant variables

Parameter	B ¹⁾	Std. Error	Confidence		Hypothesis Test			Effect of the variable on accidents ³⁾
			Lower	Upper	Wald Chi-Square	df	Sig. ²⁾	
Basic risk	-5,973	,2789	-6,519	-5,426	458,778	1	,000	0,0025
Light and sound, 80 km/h	-1,991	1,0053	-3,961	-,021	3,922	1	,048	0,14
Light and sound, < 80 km/h	-1,387	,2723	-1,921	-,854	25,949	1	,000	0,25
Other safety dev, 80 km/h	-3,367	,2976	-3,950	-2,783	127,933	1	,000	0,03
Other safety dev, < 80 km/h	-3,691	,2235	-4,129	-3,253	272,742	1	,000	0,02
No safety dev., 80 km/h	-,393	,1388	-,665	-,121	8,012	1	,005	0,68
No safety dev., < 80 km/h	0	.	.	.	.	.	.	1
AADT >100	-1,940	,2592	-2,448	-1,432	56,037	1	,000	0,14
AADT 10-100	-,850	,1916	-1,226	-,475	19,684	1	,000	0,43
AADT <10	0	.	.	.	.	.	.	1,00
Removed sight dist.< 40 %	,267	,1299	,013	,522	4,240	1	,039	1,31
Removed sight dist.>=40 %	0	.	.	.	.	.	.	1
Gravel road	-,297	,1573	-,606	,011	3,575	1	,059	0,74
Paved road	0	.	.	.	.	.	.	1
Speed limit on rail >=110 km/h	-,497	,1610	-,813	-,182	9,547	1	,002	0,61
Speed limit on rail < 110 km/h	0	.	.	.	.	.	.	1
Trains/day	,510	,0743	,364	,655	47,037	1	,000	Daily trains ^{0,510}

Degree of explanation (share of the variation explained by the model of all systematic variation):60.4%

K-value (to be used in combining accident history and accident model values):2,1

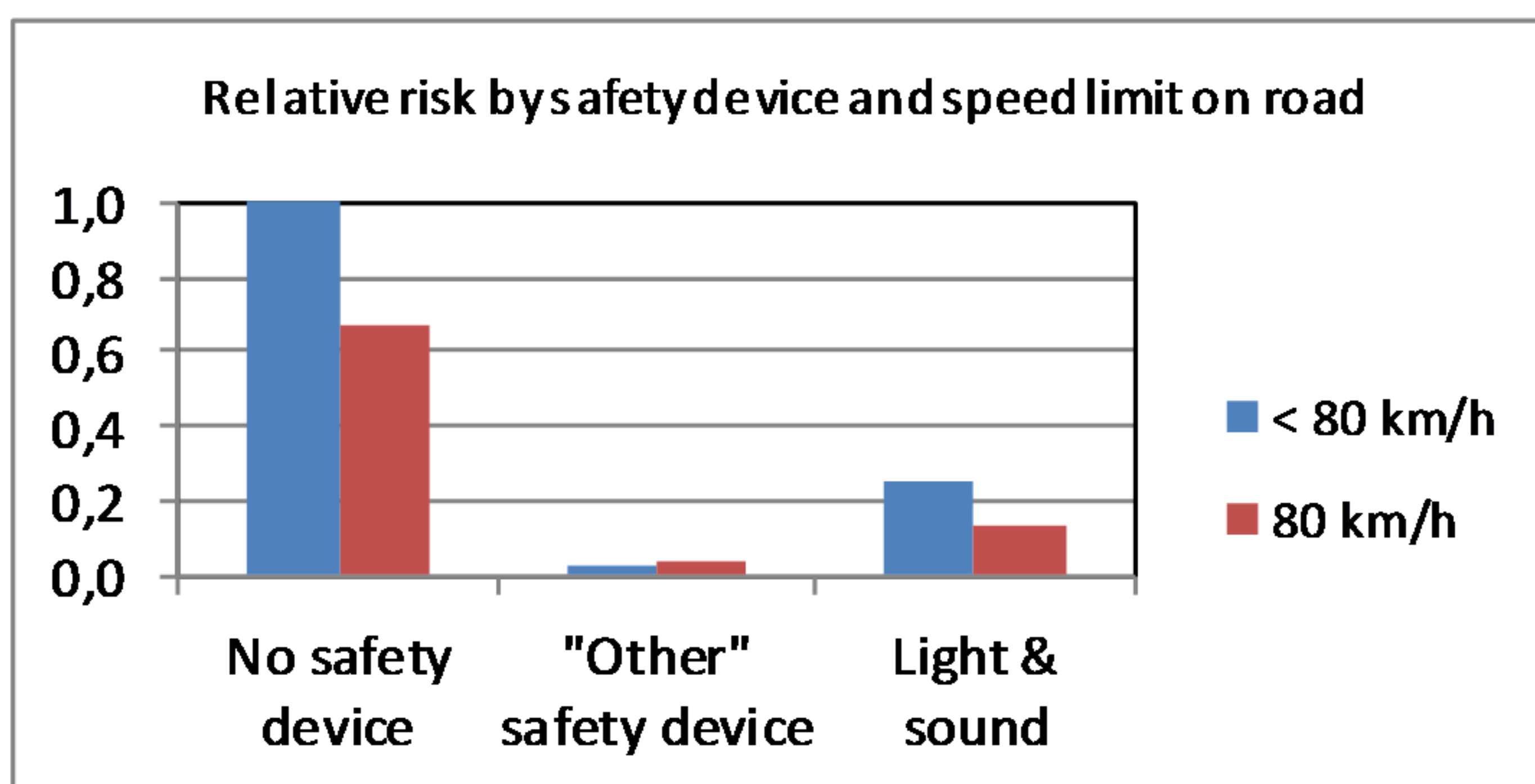
- 1) Parameter in the General Linear Model to be compared with the following columns but interpretation of the effect can be seen in the column "Effect of the variable on accidents"
- 2) All the variables in the model are statistically significant. Significance means the probability of the effect being caused by random variation (e.g. 0.010 = 99% level of confidence)
- 3) Basic risk means the number of accidents per given number of arriving vehicles if all the variables have basic values (have effect 1 in the last column). Effects of the other variables mean: by which coefficients the basic risk is multiplied in those conditions. See explanation of the results on the next page.

APPENDIX 1/2: ACCIDENT PREDICTION MODEL EXPLAINED

Explanation of the results: "Prediction model for all level crossing accidents"

1) Basic risk (0.0025) describes how many accidents occur yearly per 100 road vehicles arriving at the level crossing in so-called basic conditions (1 in column "Effect of the variable on accidents" (no safety device, speed limit <80 km/h on road, AADT less than 10 vehicles/day, share of shortest sight distance more than 40% from the required, paved road, speed limit on the rail < 110km/h). NOTE: only 0.01 trains a day on the track. Basic situation is purely a modelling technique; it is not the average situation or anything similar. For comparison with road crossing risks, real risk figures should be used instead.

2) The effect of safety devices and speed limit on the road are not independent of each other but interact. It is easiest to figure out the effects from the table and figure below. Relative risk is 1 without safety devices and a speed limit of less than 80 km/h on the road. Risks are generally highest without safety devices and lowest with other than light and sound devices (meaning safety barriers). At safety barriers and speed limit 80 km/h on the road, the risk is 40% higher than for lower speed limits. But with light and sound and without safety devices the effect of the speed limit is opposite to the risk.



Relative risk	Speed limit on road	
	< 80 km/h	80 km/h
No safety device	1,000	0,675
"Other" safety device	0,025	0,034
Light & sound	0,250	0,137

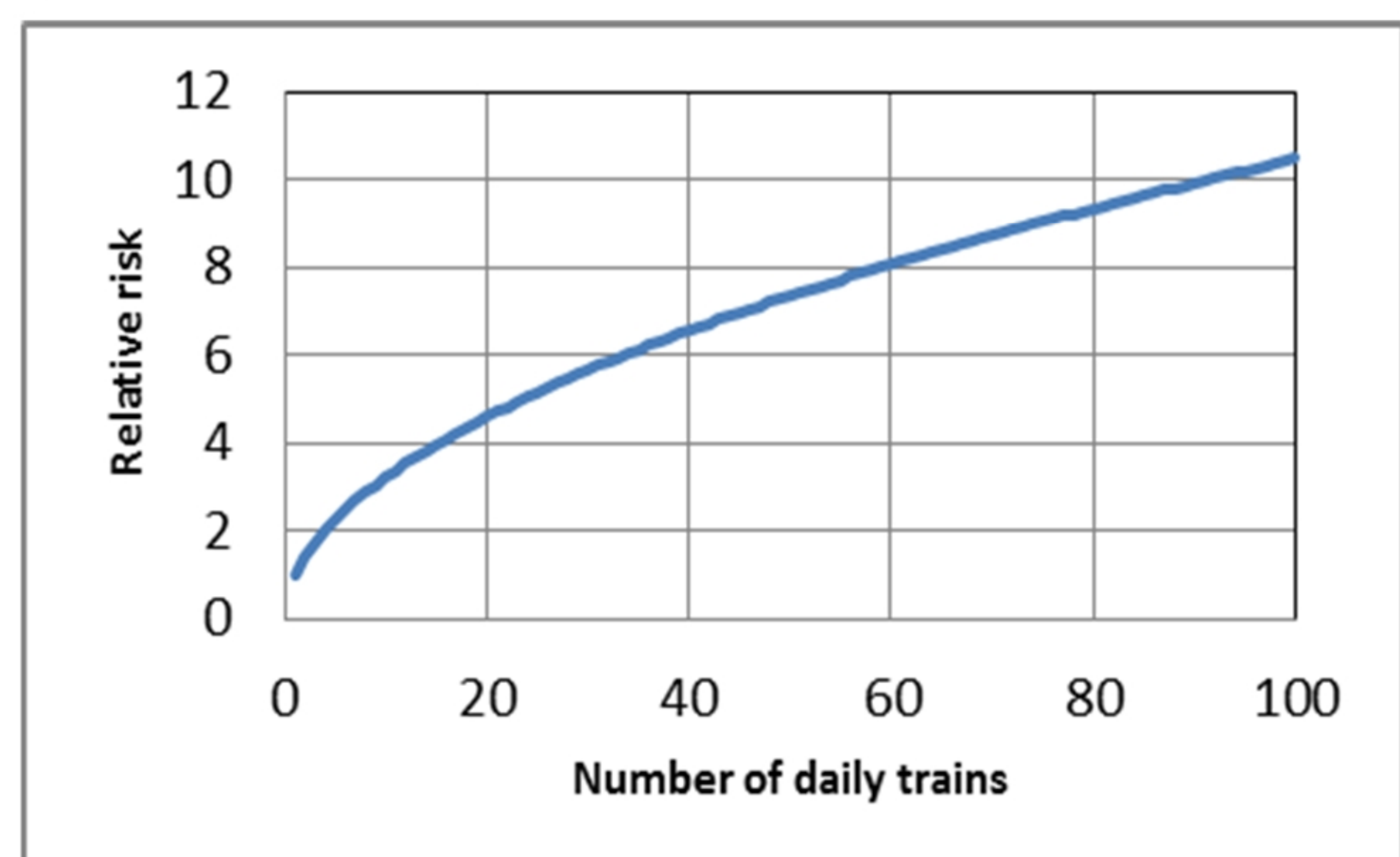
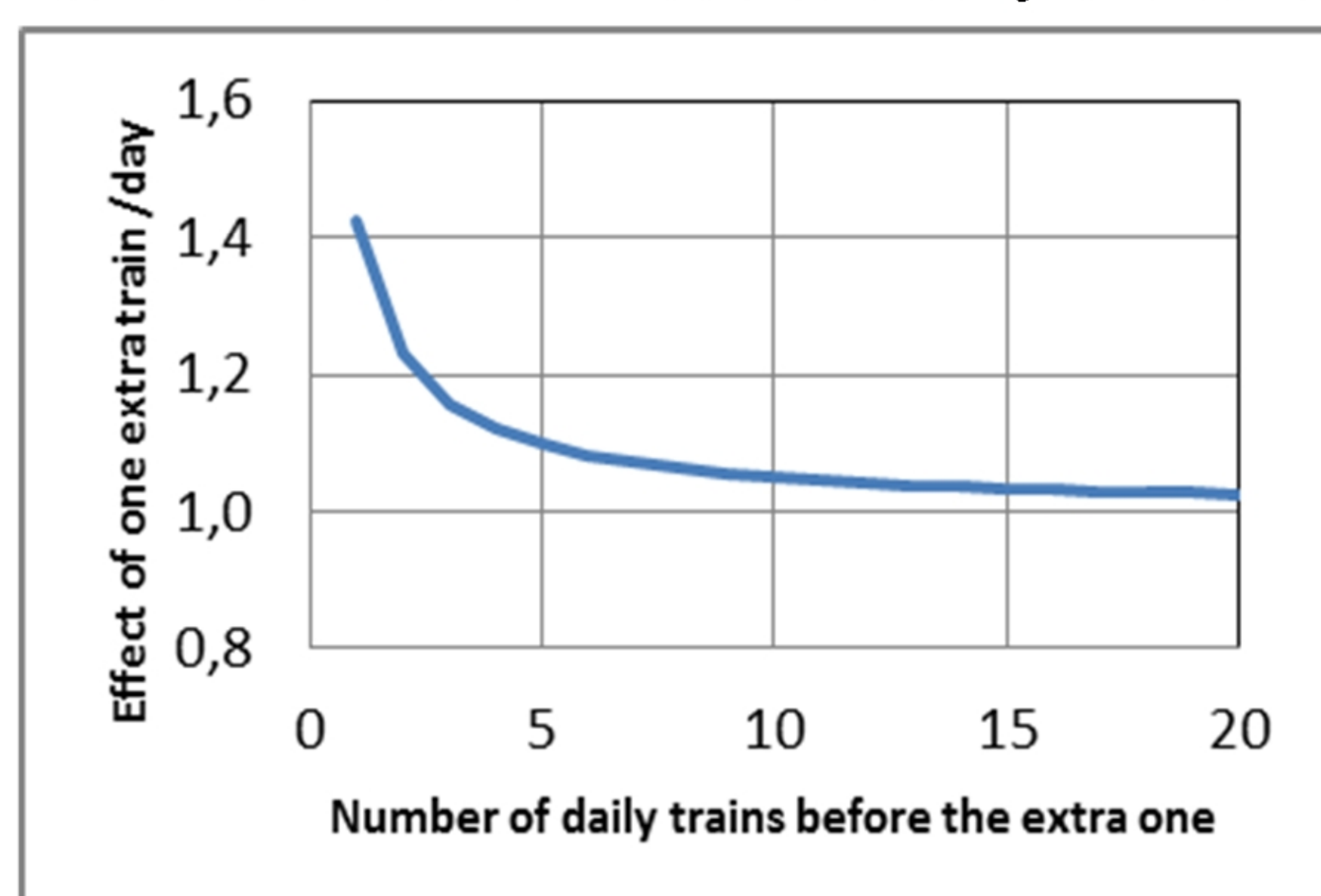
3) In the basic situation the AADT is less than 10 vehicles/day. At 10 - 100 vehicles/day the risk is 43% of that in the basic situation, and at over 100 vehicles/day the risk is 14% of that in the basic situation. Thus the increased number of vehicles/day is related to lower risks/vehicles.

4) If share of the shortest 8 m sight distance is less than 40% of that required even after removing bushes, the risk is 31% higher than in the basic condition, meaning that in better sight conditions (sight distances estimated after bush removal from sight areas).

5) At level crossings with gravel roads the risk is 74% of that at level crossings on paved roads.

6) When the speed limit on the railway is at least 110 km/h, the risk is 61% of that at other level crossings. This is one example of lower risk with higher speed limit, a result usually brought about by several improvements in conditions that often cannot be included in accident models. This is a common result also in several road accident models.

7) The effect of daily number of trains on risk is represented in two figures. The left one shows how much one extra train increases the risk (e.g. increasing number of daily trains 2 → 3 increases risk by a coefficient of 1.23, but a change of 10 → 11 trains increases the risk by a coefficient of 1.05). The right-hand figure explains the relative risk with a given number of daily trains compared to only one. E.g. increasing the number of daily trains from 1 to 10 increases the risk by a coefficient of 3.24.



APPENDIX 2: EXAMPLE OF DEFINED MEASURES IN TARVALC

Measure number	Brief description	CMF ¹⁾	Implementation cost, 1000 € ²⁾	Life time ³⁾ expectancy
0	Estimate of current safety	1	0	1
101	Light and sound, when earlier only warning signs	0.7	50	20
102	Half barriers, when earlier light and sound warning	0.5	130	20
103	Half barriers, when earlier no warning signs	0.3	150	20
104	Half barriers replaced with full barriers	0.75	50	20
105	New level crossing warning light, when earlier unprotected	0.8	15	20
201	Improving sight distances, when earlier poor	0.75	20	20
202	Improving sight distances, when earlier not a poor	0.85	20	20
203	Reducing road vehicle speeds, when poor sight distances	0.75	10	5
204	Reducing road vehicle speeds, when good sight distances	0.85	10	5
205	Discouraging circling around barriers by painting etc.	0.95	5	5
206	Light improvement at a level crossing (LC)	0.95	5	5
301	Enabling whistle under poor sight conditions	0.8	1	5
302	Adding a warning sign, when poor sight distances	0.95	1	5
303	STOP sign, when sight distances good only near the track	0.75	1	5
304	Road vehicle activating a sign warning of a track	0.9	5	5
305	Pre-warning of a STOP-sign, when bad sight distances	0.95	1	5
306	Adding a crossbars warning sign	0.95	2	5
307	Preventing access to LC by heavy vehicles or similar	0.85	1	20
401	Fundamental improvement of LC	0.7	100	20
402	Building a new LC	0	1000	20
403	Closing LC, traffic to a gradient crossing	0.20	50	20
404	Closing LC, traffic to a LC with barriers	0.35	50	20
405	Closing LC, traffic to a LC with light and sound warning	0.85	50	20
406	Closing LC, traffic to a better unprotected LC	0.95	50	20
407	Enhancing angle between road and track, when poor	0.9	300	20
408	Preventing movement around barriers physically	0.75	50	20

Notes:

- 1) To be used in the formula: Expected accidents = Target accidents * CMF
- 2) Default for implementation costs for calculating cost effectiveness if the user does not give the costs
- 3) Life-time span for deciding how many years the safety effects will be effective